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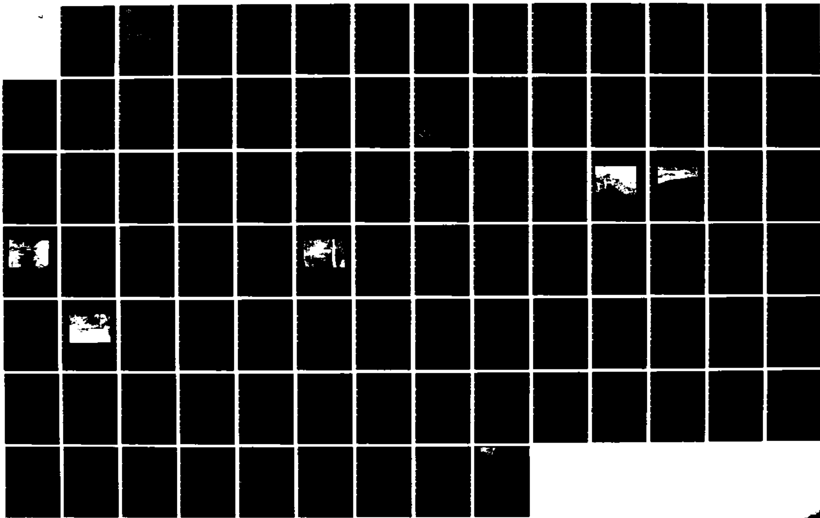

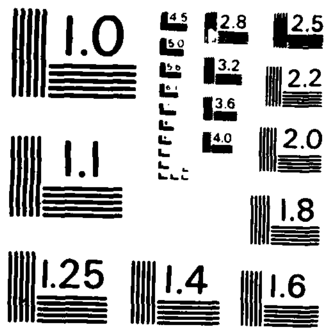

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An Evaluation of River Restoration Techniques in Northwestern Ohio

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Evaluation study of the stream restoration technique developed by George Palmiter in northwestern Ohio indicates that they may be suitable as a non-structural measure for selected areas experiencing chronic, low-intensity flooding, particularly where larger structural measures are not justified. The techniques are not appropriate for severe flood problems.

The report evaluates the Palmiter techniques based on their effectiveness and facility of planning and execution as compared to the objectives and criticisms of traditional channelization techniques: hydraulic capacity

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floating debris and sediment removal, and biological effects. While this evaluation is not based on an assessment of effectiveness over a period of time, including need for maintenance, the results are of interest to those contemplating the use of the techniques either alone or in combination with other flood damage reduction measures.

AN EVALUATION OF
RIVER RESTORATION TECHNIQUES
IN NORTHWESTERN OHIO

by

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FOREWORD

During the 1970's, George Palmiter, a railroad switchman interested in canoeing, began to devise ways to unclog and restore stretches of debris- and silt-laden rivers in northwestern Ohio with the intent of reducing flooding, obstruction, and erosion problems. Encouraged by the results, Mr. Palmiter brought his methods to the attention of interested government agencies.

As part of the Corps of Engineers, Institute for Water Resources, continuing research and policy analysis program to examine new methods and promising technologies, the Institute of Environmental Sciences at Miami University, Oxford, Ohio, was contracted to evaluate the use of the Palmiter River restoration method in northwestern Ohio. That work also produced instructional materials on the use of the restoration techniques, including a manual and three slide/tape programs.

Although a more complete analysis would necessitate follow-up evaluation of technique effectiveness, including maintenance, over an extended period of time, it may be suitable as a non-structural measure for selected areas experiencing chronic, low-intensity flooding, particularly where larger structural measures are not justified. It, however, is apparent that the Palmiter method would not be appropriate for severe flood problems. This evaluation has been prepared for use by those parties interested in the use of this technique alone or in combination with other flood damage reduction measures.

ACKNOWLEDGMENTS

A number of people and organizations made important contributions to this project. The U. S. Fish and Wildlife Service, Columbus, Ohio, helped with field work. Pam Miller, while a graduate assistant with the Institute of Environmental Sciences, made major contributions to the field studies. Susan Sandro did the field interviews with county officials. Dr. Thomas Wissing contributed the design for the fish shocker which was built by John Morrow. Dr. Paul Daniel provided frequent advice on field procedures and fish identification. Dan Riestenberg did much of the fish identification. Dennis Mullaly drew the maps. Thomas Collins and Neil Herbkersman did most of the photography and developed the manual, tape-slide shows, and videotape. Ruth McLeod typed the manuscript and handled correspondence on the project.

Mary Vincent and Kyle Schilling, our project monitors, provided a wealth of helpful suggestions. Their insight and patience are greatly appreciated.

Finally, we acknowledge the contributions made by George Palmiter. Without the many hours he spent with the study team, in the field and in the office, it would not have been easy to do this evaluation.

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CHAPTER 1

INTRODUCTION

In 1979, the Institute for Water Resources, U. S. Army Corps of Engineers, contracted with the Institute of Environmental Sciences, Miami University, to undertake an investigation of some river restoration techniques developed by Mr. George Palmiter, Montpelier, Ohio. These techniques had been applied in three known cases: the St. Joseph, Tiffin, and Blanchard Rivers in northwestern Ohio. See Figure 1. The general objectives of the project were to describe the techniques and how they were used, to prepare instructional materials on their use, to assess public response to their use, and to evaluate the effectiveness of the techniques in achieving bank stabilization, reduction of flooding and the maintenance of good aquatic habitat for fish and other aquatic organisms.

The project began in October, 1979. The work plan envisioned retrospective evaluation of the three rivers which had been restored between 1975 and 1978. Chemical and biological investigations, as well as hydraulic calculations, were to be done, to the extent possible, as part of the evaluations. This work plan had a number of deficiencies from a theoretical and practical standpoint. One of the most serious was the absence of observations on the streams prior to restoration work that could be used for comparison with present conditions. A second, and related, problem was the absence of records on exactly where restoration work had been done on the Tiffin and St. Joseph

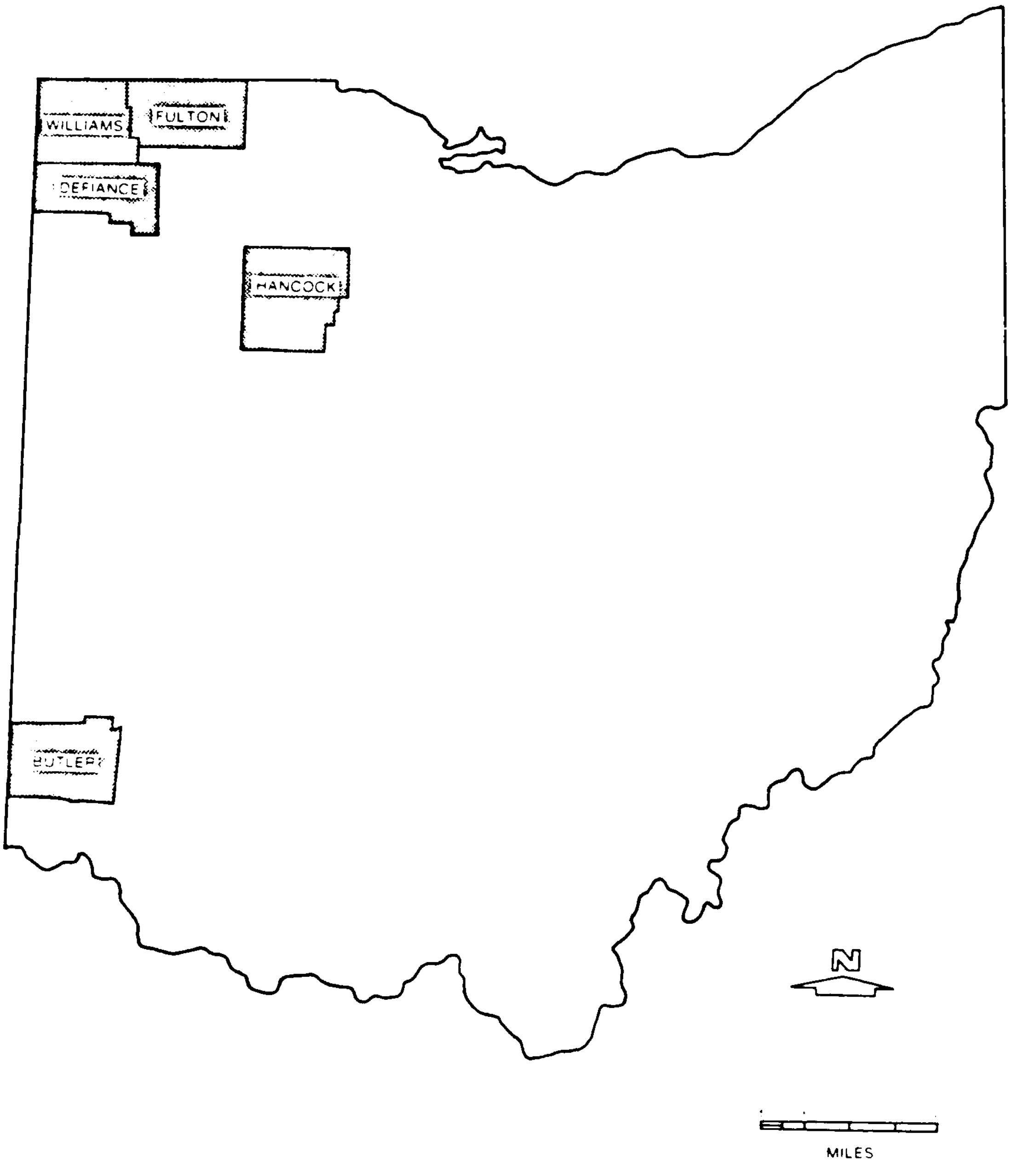

FIGURE 1. COUNTY LOCATION MAP

Rivers. A third inherent problem, though not necessarily a major handicap for a reconnaissance study, was the relatively short two-year period of time during which the investigation was to be conducted. Definitive work should extend over many years to investigate long-term effects. These deficiencies were recognized from the beginning by all parties, but at the time it appeared to be the best plan for developing a preliminary evaluation of the techniques. The initial project work was carried out with this original plan.

In early 1980, a CETA project in Williams County on the St. Joseph and Tiffin Rivers and their tributaries enabled the consideration and partial implementation of a modified study design. This design provided for studies before and after selected reaches of stream channels were "restored" by the CETA work crews. It was used, where possible, and constitutes the basis for a portion of the evaluation included in this report.

The plans for the CETA crews were thwarted, however, by weather conditions and other complications, notably a lack of equipment. Consequently, not all the planned work was executed and the evaluation was thus not as complete as was proposed in the revised design. The project investigators consider, however, that enough information was obtained to adequately describe the techniques and to make reasonable evaluations of the effectiveness of the techniques. In addition, instructional materials in the form of tape-slide shows and an accompanying manual were prepared that enable a person to understand the principles behind Palmiter's restoration techniques. Some field training and/or apprenticeship are still considered desirable, though the degree would depend upon the amount of previous experience trainees had in working on rivers.

History of Technique Development

In the 1950s and 1960s, elm trees along the St. Joseph and Tiffin Rivers were afflicted with the Dutch Elm disease. Dead trees fell into the rivers, forming many logjams which interfered with recreational boating and contributed to some increase in flooding of low-lying agricultural areas. Banks were eroding around the jams and the rivers were cutting into agricultural fields. The flooding problems were aggravated by the fact the flood plains along both of these rivers are extensive, ranging, in some places, up to a mile in width.

Mr. George Palmiter, a canoeist, duck hunter, and employee of the Norfolk and Western Railroad, was quite familiar with the two rivers, having spent a great deal of time on them through his sporting activities. On observing the increased blockage of the rivers that had occurred through time, he thought it would be possible to reduce these flooding, obstruction and erosion problems. On a small stream in the St. Joseph River system near Montpelier, he experimented with cutting debris, using the debris to protect the banks, and diverting the flow of the stream in such a manner as to remove obstacles to flow without resorting to conventional dredging. Over a period of several years, Palmiter worked with and refined the techniques to such an extent that he was successful in conducting a larger trial on the St. Joseph and Tiffin Rivers in Williams County during 1975 and 1976. In 1978, based in large part on this experience, the portion of the Blanchard River that lies in Hancock County was treated in much the same way. Mr. Palmiter was consulted on the Blanchard project, though the work was not done under his direct supervision.

The techniques used by Mr. Palmiter have received nationwide attention and publicity. He received the Conservationist of the Year award from Outdoor

Life in 1977 and a Rockefeller Public Service award in 1979. Through a network of conservation organizations, he has become well known and is much sought after as a consultant and speaker. Projects based at least in part on his approach are known to have been conducted in North Carolina, Mississippi, and Michigan. More recently, he has supervised a project on Swamp Creek in Darke County, Ohio, in 1981 and 1982.

Despite their application in various places, no scientific evaluation of the techniques was done prior to the present investigation. Mr. Palmiter relied entirely on observation, trial and error, and photographic record keeping. Other persons who supervised field crews learned what to do by apprenticeship to Mr. Palmiter.

Literature Review

The review of literature is limited to materials having a direct bearing on either the techniques being evaluated or on general considerations dealing with bank stabilization and channel capacity.

Bank Stability and Stream Restoration Techniques

There is a large body of literature on bank stability, but only brief excerpts will be drawn from those sources. While not extensive, there is also pertinent literature concerning channel restoration techniques. As will be indicated in this section, some of it describes and evaluates methodology similar to that used by Mr. Palmiter; however, there is no evidence that Palmiter has read any of the works cited here.

The earliest document found that has a direct bearing on the techniques was written in 1937 by I. L. Saveson and Virgil Overholt. In their paper on stream bank protection, the authors deplored the cutting of trees on stream

...s. "Erosion is most serious where farmers have cleared the banks of trees in order to prevent shading of their crops and to utilize their bottom land to the fullest extent. A good stand of willows, cottonwood, sycamore or black locust in many instances holds the outside bank of a stream and prevents it from eroding." (Saveson and Overholt, 1937, p. 3). Based on model and field studies, they recommended the use of deflectors on the outside bank of a stream and proposed a procedure for locating these deflectors (or jetties). This procedure has been included in subsequent SCS Agricultural Handbooks. It may be of some note that both authors are from Ohio and the cause of their concern with streambank erosion was the condition of many Ohio streams.

In a later report on work on the Winooski River in Vermont, Edminster, Atkinson, and McIntyre (1949) proposed the use of "blanket protection with large trees." In most respects, this is similar to the anchored brush piles used by Palmiter. It is referred to as a pervious revetment and is regarded as "probably the cheapest form of protection, at least as regards cost of material." In stating the purpose of this protection, they say "this and various types of pervious jetties or revetments are designed to slow the velocity of current next to the bank and cause deposition, which results in a more impervious covering and prolongs the effective life of the protection." The authors suggested using the Saveson and Overholt procedure to locate deflectors.

Oberwager (1967) reports on the use of streambank protection measures that employ, in part, steel railroad pilings backfilled with trees and brush. These measures were used on the Little Snake River in Wyoming.

Wickliff (1944) notes the importance of retaining trees on stream banks. For example, he comments on the role of "living tree roots" in resisting "the cutting action of rising waters." He also recognized the value of

bank shading for maintaining lower water temperatures which are preferable for good fish habitat.

Finally, Nunnally and Keller (1979) use the term stream restoration to denote "means for restoring flow efficiency in streams that have become debris-choked and eroded due to the direct or indirect actions of humans." They note that "compared to channelization, stream restoration involves trading off some loss in flow efficiency for a more stable channel morphology and significantly better aquatic and fluvial ecosystems." As they use the term, "stream restoration is accomplished by removing debris jams and providing fairly uniform channel cross-sections and gradients while preserving meanders, leaving as many trees as possible along stream banks, and stabilizing banks with vegetation and riprap where necessary." They go on to say that "economically, the cost of restoration is typically less than one-tenth of the cost of channelization."

For each of the procedures espoused by Palmiter, a precedent can be found in the literature. However, on two accounts, Palmiter has introduced significant elements. First, Palmiter considers the vegetal cover on the bank to be of significant value in preventing the growth of aquatic weeds and trees in the channel. Second, it is also notable that none of the precedent sources sets forth the individual procedures as a unified methodology. This does not imply, however, that the authors of the cited works would have necessarily disagreed with any of the elements or with using them in a unified way.

Channel Capacity

The continuing quest for better methods of estimating the hydraulic resistance of both natural and constructed channels is germane to the evaluation of the hydraulic effectiveness of the techniques. As is noted in Chapter 3, on hydraulic capacity, more assumption than measurement is typically made.

However, a citation from Chow (1959) will illustrate the importance of the issue and the range of assumptions.

Chow (1959, p. 112) cites normal values of Manning's n for natural streams ranging from 0.030 to 0.100 and for excavated or dredged channels values ranging from 0.018 to 0.100. He also cites an investigation of a drainage ditch in Illinois to determine the effect of vegetation on the coefficient of roughness. When the channel was in "good condition," the value of n was 0.033. A year later, with bushy willows and dry weed on the side slopes, n was 0.055. "The n value at medium summer stages was about 0.115 and at a nearly bankfull stage it was 0.099." The conclusions drawn from this investigation were, in part, that the minimum value of n for designing drainage ditches in central Illinois should be 0.040. To use this value, the channel should be "cleared annually of all weeds and brush." "A value of n = 0.050 should be used if the channel is to be cleared in alternate years only. In channels that are not cleared for a number of years, the growth may become so abundant that values of n > 0.100 may be found." (Chow, 1959, p. 102)

The effects of logjams have received little direct attention in the literature. However, there is some consideration of the effects of such phenomena on channel form and fluvial processes. The literature topic is large organic debris. Much of this literature focuses on steep western streams. However, in one paper by Keller and Swanson (1979), some low gradient meandering streams were considered. Three streams in North Carolina and Indiana were studied. These streams have gradients on the order of several meters per kilometer. The conclusions cited in that paper include the following:

1. "Large organic debris dams in low gradient meandering streams of moderate size are often associated with streambank erosion and in-channel

deposition which locally may greatly increase channel width; may in specific instances facilitate the development of meander cutoff; and may produce midchannel bars and thus a short braided reach in an otherwise meandering channel."

2. "Living or dead trees anchored by rootwads into a streambank may greatly retard bank erosion. Once a tree falls into the channel it may reside there a long time and depending on the size of the stream and other factors may greatly affect channel form and process."

Setting

The St. Joseph and Tiffin Rivers in Williams County, Ohio, where the CETA project was conducted, were the principal stream systems investigated. This area is part of the Till Plains section of the Central Lowlands physiographic province. See Figure 2. "The Till Plains section is characterized by relatively flat to moderately steep topography and is poorly drained, as suggested by the presence of deranged drainage and numerous swamps and ponds. This area includes two partially dissected, northeast-trending glacial end moraines separated by areas of ground moraine, outwash, and alluvial material. These moraines, the Wabash in the northwest corner of the county and the Fort Wayne in the center, control drainage throughout the county, although they are relatively minor topographic features. The Fort Wayne Moraine forms a surface-water divide which separates the drainage basins of the Tiffin and St. Joseph rivers, the latter of which drains most of the Till Plains section."

"The Lake Plains section in the southeastern corner of Williams County is a flat to gently undulating area that is drained by the Tiffin River and its tributaries. This section is separated from the Till Plains section to

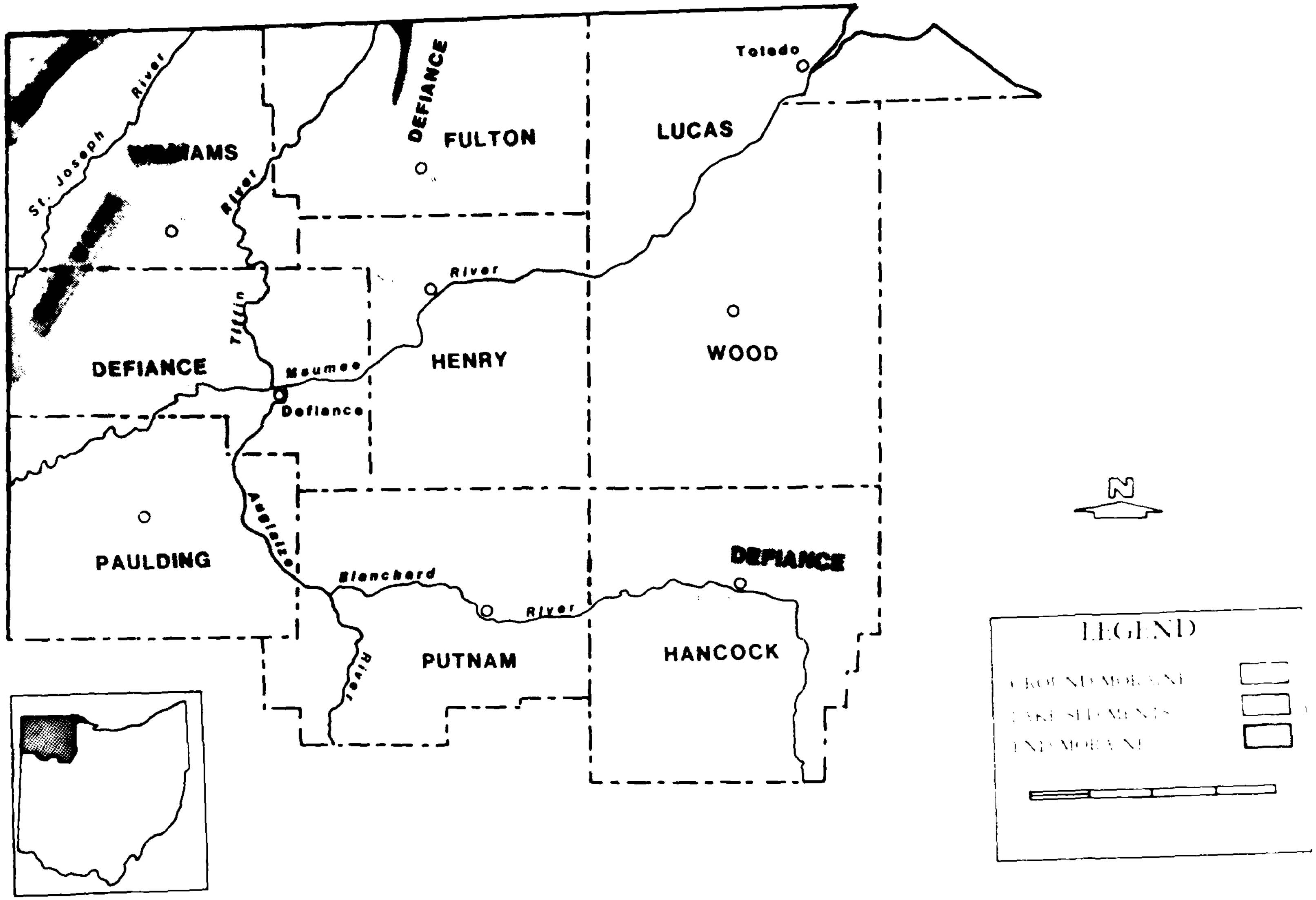

FIGURE 2. PHYSIOGRAPHIC FEATURES OF NORTHWESTERN OHIO

the northwest by discontinuous beach ridges that parallel the eastern flank of the Fort Wayne Moraine and mark the strandlines of Wisconsin proglacial lakes formed by ice-damming of meltwater during the northeasterly retreat of the ice sheets." (King, 1977, p. 4)

"Both the Tiffin River and the St. Joseph River arise from drainage in southern Michigan and flow to the southwest. The Tiffin River, with an average fall of 1.2 feet per mile, flows into the Maumee River near Defiance . . . . The St. Joseph River has an average fall of 1.6 feet per mile and flows into Indiana where it joins the Maumee River north of Fort Wayne." (King, 1977, p. 32) In Fulton County, where the hydraulic capacity analysis discussed in a later chapter was done, the average slopes on the Tiffin River are about 2 feet per mile. In Williams County, the average slope on the Tiffin is about 1 foot per mile." (Poggemeyer, 1976)

Average annual temperature in Williams County is about 50° F. "Annual precipitation commonly ranges from 30 to 35 inches, although yearly totals as high as 52 inches and as low as 19 inches have been recorded. Average annual precipitation for the county is just less than 34 inches." (King, 1977, p. 6)

The mean annual flow rate for the Tiffin River at Stryker for water years 1922 to 1976 is 310 cubic feet per second (cfs) or 0.75 cfs per square mile. For the St. Joseph River at Newville, Indiana, southwest of Edgerton, for the water years 1948 to 1976, the mean annual discharge is 495 cfs, 0.8 cfs per square mile. (King, 1977, p. 36)

A portion of the upper Tiffin River in Fulton County is diked, but the remainder of the stream is unconfined. Flood plains are over a mile wide in several areas above Stryker. Below Stryker, the stream is "more entrenched with definite secondary banks defining the flood plain areas. The average width of the flood plain is about 700 feet." (Poggemeyer, 1976, p. 4)

Selected water quality parameters for the Tiffin and Blanchard Rivers are given in Table 1.

Table 1. Selected Water Quality Characteristics, Tiffin and Blanchard Rivers

	Tiffin River at Evansport	Blanchard River near Findlay
pH	8.3	7.5
Alkalinity, mg/l	216.	147.
Hardness, mg/l	319.	274.
Total dissolved solids, mg/l	435.	505.
Chloride, mg/l	36.	41.
Sulfate	78.	140.

1. All values are means calculated from a 20 percent sample of data provided by the U. S. Geological Survey.

2. Period of record used:

   Tiffin River at Evansport--July, 1968-March, 1976
   Blanchard River near Findlay--October, 1968-June, 1977

CHAPTER 2

DESCRIPTION OF RESTORATION TECHNIQUES

The river restoration techniques developed by George Palmiter evolved through experimentation over a period of years. One can only conjecture about the exact sequence of events that led to the system he now uses. However, the broad outline of technique development seems to be reasonably clear. Mr. Palmiter had spent a great deal of time on the rivers of northwest Ohio and the adjacent states as a canoeist and duckhunter. Over the three-year period during which the study team interacted with Mr. Palmiter (1978-1981), it became apparent that his powers of observation are very well developed. Thus, his approach of experimentation and observation, supplemented by effective use of photography to record changes through time, served him well in building a body of knowledge he could apply to a new situation.

As there was no previous written documentation of the techniques, it was necessary for the study team to observe the use and results of the techniques in the field and supplement these observations with extensive interviews with Mr. Palmiter. Inasmuch as each river has its own unique properties and variations on the techniques have been applied in each situation, it took some time to develop a comprehensive understanding of them. However, it is believed that this study has come to an accurate understanding of the basic principles and some of the nuances.

As one of the products of this study, a supplemental package of instructional materials has been prepared, consisting of three tape-slide shows, an instructional manual (Institute of Environmental Sciences, 1982) or guide to the techniques that parallels the shows, and a videotape. Mr. Palmiter has seen these materials and has given a general endorsement of the content. Thus, the instructional materials, together with the material in this chapter, present a fairly accurate depiction of how, why and where these techniques may be used. Wherever possible, aspects of the techniques that Mr. Palmiter describes in unconventional terminology have been expressed in the terminology of the scientific and engineering communities.

Basic Principles

Palmiter frequently uses the expression "Let the river do the work." In a larger sense, this principle underlies the entire set of techniques. The river current is employed in different ways to move sediment and debris. For example, the current may be used along certain reaches to remove sand and gravel bars which are either restricting flow or deflecting the current against the bank, thereby causing unwanted erosion. In other instances, the current may be used to float large logs and brush to a location on the bank where severe erosion is taking place. Once in its proper position, this material is wired in place and acts as a deflector of the current away from erosionally-sensitive areas. Ultimately, suspended sediment settles out in the slack water behind the brush and logs and these sites become areas of sediment accumulation rather than erosion. Not only does the current remove sediment from bars but it also cuts from areas where it is "unwanted" and fills in areas where it is "wanted."

The specific techniques used in river restoration include the following:

1. Debris is removed from the channel with minimal disruption of the stream, usually in a labor-intensive manner.
2. Bank protection is provided by building piles of brush on eroding banks and securing them with cables, wire, or twine.
3. Bars are removed, ordinarily by reducing the resistance of the bar to erosion and then directing flowing water against the bar in such a manner as to remove the bar over a period of time.
4. Potential obstructions, such as dead trees or trees leaning over the channel with inadequate root support, are either removed or are trimmed to reduce the likelihood of the tree's falling into the channel.
5. Vegetation is started, if not already present, on the banks to provide bank stabilization with the roots and to provide shading of the stream. Shading, if sufficiently dense, will reduce or prevent the growth of aquatic plants in the channel and provide cooler water temperatures. Such plants significantly reduce hydraulic capacity, leading to reduction of velocity and deposition of sediment. In turn, the sediment buildup promotes the growth of more aquatic herbaceous or woody growth. Clearly, the reduction or elimination of these obstructions helps maintain a stable channel.
6. Periodic inspection of the river is done to observe the behavior of the river in response to the application of these techniques and to take additional corrective action.

Planning for restoration of a channel is primarily a qualitative exercise. Formal topographic surveying is not done, nor are quantitative measurements

of any kind normally employed. Rather, the river is inspected both from the air and on the ground, and judgments are made about what is to be done in each part of the river based on the above principles. These proposed actions are recorded on maps, field notes and, in some instances, photographs that are then used to direct field operations.

The Meaning of Restoration

Restoration implies returning something to an earlier state. Although this is to some extent an accurate term to describe Palmiter's techniques, it is in need of further explanation. For example, one definition of river restoration might be the return of the river to a condition that existed before man's activities altered some property of the channel. In contrast, however, Palmiter's techniques are not necessarily intended to achieve the above-mentioned goal. Rather, restoration is used in the sense of improving the hydraulic characteristics of the channel to a level approximating the capacity prior to the formation of extensive and numerous obstructions, such as the logjams of the Tiffin and St. Joseph Rivers. Also implied in this definition is the maintenance of high quality aquatic habitat and the reduction of bank erosion.

Thus, restoration is an attractive and, on the whole, an appropriate term to describe Palmiter's work. It is clear, however, that by endeavoring to increase the hydraulic capacity of a reach by straightening, removing bars and deepening the channel the stream may be altered to a state quite different from that which existed prior to man's intervention into the stream. The amount of change that is brought about, however, is difficult to evaluate because of the lack of early records.

The Six Basic Techniques

The six basic techniques used in the Palmiter approach to river restoration are described in this section. The sequence is the same as in the instructional manual written for this project. However, more detailed explanation and commentary are supplied here.

Removal of Log Jams and Debris

Fallen trees, log jams, and debris of other kinds alter the flow characteristics of a stream and slow the current immediately upstream from the obstruction. Sediment tends to be deposited in these low-velocity regions because the capacity of the current to move sediments is reduced. These obstacles to flow also may divert the current into one of the banks, causing erosion. Removal of these obstacles increases flow velocity, reduces bank erosion and often causes bars in the central part of the channel to be attacked by the current.

The removal of these obstacles is ordinarily done by hand labor, with the aid of small tools (chain saws, reciprocating saws, winches or block and tackle, axes, bow saws, etc.) at time of low river stages. Some of the work may be done from small boats or barges. In a recent river restoration project in Michigan, for example, a barge with a hoist was constructed to move heavy logs in the wide channel. Occasionally, tractors, horses, hoists, or front-end loaders may be used to help pull or move material.

Some of the material removed from the channel is used to protect eroding banks and/or to divert flow toward a bar that is restricting flow. The remainder of the material is allowed to float on downstream. The disposition of this material is one of the points of contention about the techniques. Mr. Palmiter contends that some of the material that floats downstream will be

carried by water onto the flood plain during floods where it will eventually rot, while the smaller material will continue downstream, causing no problems. Others contend that the material left to float downstream will catch on downstream bridge piers and form other jams, perhaps more destructive than the original one.

Observations lend evidence to each side of the argument. The study team has noted debris cut from logjams that found its way onto the flood plains where it was, indeed, rotting away, but there was no way to determine the origin of the material. The team also saw examples of debris catching on downstream bridge piers. Some of the controlling factors seem to be how wide the flood plains are below the place where the debris is released, whether there are suitable entries to the flood plain from the main channel, and how far downstream the piers are that could provide a lodging place for the debris. The decision on whether to completely remove the debris from the channel or to cut it into short lengths to minimize problems downstream has to be made on a "case-by-case" basis. Distance from roads and the attaining of permission from land owners are two factors of prime importance.

Protection of Eroded Banks

Bank protection is provided in two ways. First, current that had been directed toward the bank by a fallen tree or logjam, thereby undercutting and continually eating it away, is directed away from the bank by removing the obstruction.

Second, the woody, brushy material removed from the channel, often supplemented with material taken from nearby areas, is placed and secured on the side of the eroding bank. These brush piles divert current away from the bank into the main channel. In addition, the velocity of the current is

decreased in the brush pile and immediately downstream from it, allowing sediments to be deposited there.

Brush piles are placed throughout the eroded reach. They need not be continuous. To some extent, placement can be trial and error. After each pile is placed, the points where the current is next directed toward the bank mark the place where the next pile can be placed.

These brush piles are a form of training works. They have the advantage of being permeable structures. They bend and give as they are stressed by the current, and they induce sedimentation next to the bank. Less flexible, rigid and impermeable structures are more subject to erosion behind and under the structures, particularly if on inadequate foundations.

Once set in place, the brush piles are secured with cable, wire, rope, or twine. Where velocities are expected to be high, cable or wire is a virtual necessity. Where there are no natural features for attachment of the cables, posts or stakes may be placed in the bank to serve as anchors. This is less satisfactory than using existing stumps or trees, but it will work. There are times when there is no alternative.

The brush piles are remarkably effective in providing bank protection. They are also quite durable when properly constructed. While some of the material will rot over time, trees can grow in the piles and sediment will be trapped in them, actually strengthening them and making them very durable. They appear to have superiority over riprap for bank protection.

Removal of Bars

Where bars are judged to be reducing channel hydraulic capacity, contributing to erosion, or for some other reason are detrimental to the desired character of the reach, the bar is removed. The procedure is more complex and time-consuming than is the procedure for removal of jams.

An early step is the removal of vegetation from the surface of the bar. This may go as far as pulling stumps and roots, using heavy equipment.

The remaining steps involve inducing erosion of the bar by deflection of current toward the bar and/or the establishment of pilot channels. Current deflectors may be brush piles anchored in the channel or trees cut part way through and pushed over into the channel. Pilot channels may be dug by hand or with power equipment. The pilot channel must divert enough flow to begin the erosion process which will then continue until the bar is cut away. More experimentation and readjustment is required with these two techniques to achieve the desired results than is the case with the bank protection methods described above.

Removal of Potential Obstructions

Potential obstructions are objects, usually trees, in danger of falling into the channel. A standing dead tree or a tree severely leaning over the channel is the most common case. If further bank cutting occurs, or the tree root structure becomes too weak to hold it, the tree will fall into the channel creating an obstruction to flow. The remedies are either removal of the obstacle or reducing the likelihood of its falling into the channel. When the tree is cut completely, the stump and its roots are usually left in place. When lesser remedies are used, they include topping the tree or cutting off branches.

There may be other kinds of potential obstructions than trees. Man-made structures, such as old bridge piers, are found along the banks of channels and can be potential obstructions. Junked appliances, automobiles, etc., are also sometimes found in stream channels. The remedy for such obstructions is removal from the channel.

Revegetation

Vegetation is one of the most important elements in the set of restoration techniques, because it increases bank stability and provides shade along the sides of the channel. Bank stability is enhanced by the root structure as well as the effect vegetation has in inducing sedimentation.

The role of shade is more complex. Shade acts to inhibit the establishment of aquatic plants in the channel and thereby reduces the likelihood of sediment deposition in the main channel. Also, because shade slows the growth of existing plants, it serves to maintain the hydraulic resistance of the channel at a relatively constant level.

The advantages of shade can readily be appreciated if it is suddenly removed. In such cases, it is not uncommon to have dense weedy growths within the first year after removal. Under such conditions, Manning's "n" values will increase considerably, enough to reduce much of the increased hydraulic capacity that would be gained by removal of obstructions, and is a key reason why the expected hydraulic capacity gains from channelization are not always actually experienced.

Other benefits from shade development include more favorable habitat for fish and wildlife. Habitat improvement comes in part from the presence of cooler water. The other major factor is an improved food supply for the aquatic ecosystem, achieved through the detritus deposited in the channel from the riparian vegetation.

Revegetation is achieved in successional stages, with the end stage being a mature stand of trees. The restoration techniques take advantage of the natural process and expedite it through the planting of fast-growing and water-tolerant species. The willow is most commonly used as a pioneer species,

not only because it has both these characteristics, but also because it is usually readily accessible and will grow from cuttings. Cuttings are made from stands in the vicinity and pushed into the soil. Some of the cuttings are planted in the brush piles that were established for bank protection; others are planted on the banks.

Maintenance

The final step of the techniques is maintenance. After a reach of a river has been restored, periodic reexaminations and maintenance are necessary to correct any new problems, to check on the effects of previous work and to make modifications. For example, on the Blanchard River, on which the major restoration work was done in 1978, a severe windstorm hit the area in the following year, bringing down a number of healthy trees into the river. In such a case, a reexamination can lead to timely removal of such trees.

The considerations that should guide the period between inspections are high water events and severe storms or other events that might lead to deposition of unwanted debris in the stream. After the initial restoration work, inspections following the next few periods of high water are in order. In the absence of severe storms that might deposit debris in the stream, annual or semi-annual inspections are regarded adequate by Mr. Palmiter.

It should be noted that there has not been much testing of the inspection frequency. While Mr. Palmiter has done some ad hoc inspection of the St. Joseph, Tiffin, and other streams that have been restored, he has not been funded to do such inspections. Thus, there has not been a systematic inspection program as a rule. On the Blanchard River in Hancock County, there has been a funded inspection program for two years. The person doing the inspection has had no particular training for the function and has not been involved

in any of the restoration projects. He is, however, a long-time resident of the area and is familiar with the river.

Maintenance work is done using the same techniques as employed on the original work. The principal exception is that maintenance would be done on a more ad hoc basis. The maintenance and inspection program requires the services of inspectors and work crews. One inspector should be able to cover several miles a day. While not essential, winter aerial reconnaissance would be useful in the inspection program. A competent inspector operating with a helicopter or light airplane would be able to cover a large territory with ease, limiting ground-level inspections to trouble areas spotted from the air.

CHAPTER 3

EFFECTS ON HYDRAULIC CAPACITY

Channel modification is often undertaken primarily to increase hydraulic capacity of the channel. An evaluation of the effects of the river restoration techniques on hydraulic capacity has been made and the overall evaluation is favorable. However, the empirical evidence is scanty and the conclusions reached by the study team should be judged accordingly. The process used in the evaluation, the assumptions, and the import of the evaluation are described below.

A comprehensive evaluation of effects on hydraulic capacity was not performed and cannot be done without extensive instrumentation of a stream(s), careful observation of the stream(s) over a period of several years, and detailed calculations of water surface profiles and bed elevations for a variety of conditions.

It must also be noted that not enough information is available in the literature to undertake a fully satisfactory hydraulic analysis. For example, no systematic investigation of head loss across logjams was found in the literature. Discussions with personnel of the Waterways Experiment Station and the U. S. Geological Survey did not uncover any unpublished information that could be used.

A few observations of channel cross-section, discharge, and water surface profile were made in the present study. Detailed cross-section information

was available for the Fulton County portion of the Tiffin River. Water surface profile calculations were made for portions of this reach of the Tiffin River using a standard-step water surface profile method. Assumptions concerning channel roughness were made based on the appearance of the stream. These were used in selecting values of Manning's n and estimating the damming effects of logjams.

Channel Design

Many of the channel-modification projects performed in northwestern Ohio are done by the counties, using design plans drawn either by the county engineer or by consulting engineers. These design studies typically include cross-section and channel slope surveys and are used both for hydraulic calculations and for estimating earthwork quantities. Channel slope may be inferred either from thalweg elevations or actual water surface profiles. Measurements of streamflow are rarely made, though existing stream gages, if available, may be used in conjunction with water surface profile data. The Manning formula is normally used to estimate the relationships among discharge and slope, hydraulic radius, area, and hydraulic roughness. The hydraulic roughness is estimated using U. S. Geological Survey photographs, tables, or formulas such as those in Chow (1959). An assumption often made in estimating the effect on hydraulic capacity of a channel modification is that the cross-section and hydraulic roughness of the channel will remain unchanged indefinitely.

In some designs, only normal depth calculations are used in estimating channel capacity and water surface profiles. In the better work, water surface profiles are calculated using one of the backwater curve methods, such as the standard-step method (Chow, 1959). Many consulting firms and county engineers

do not as yet use computers in their work, which limits the amount of analysis likely to be put into the hydraulic design of a channel modification project. Thus, it is not uncommon to have a design based on a small number of long reaches and with only a small amount of cross-sectional and slope data used in the calculations. A case in point is the study on the Tiffin River in Fulton County mentioned above. Here, the hydraulic roughness after construction was considered to be 0.020 in the main channel and 0.070 in the flood plain. Water surface profiles were based on a small number of cross-sections, with reach lengths averaging 2-3 miles (Mekus, 1980).

Qualitative Assessment of Effects

The study to assess effects of the Palmiter restoration techniques on hydraulic capacity began by considering qualitatively what happens in their application. As indicated in the previous section, the qualitative assessment of effects is necessary, and it conditions the assumptions used in the calculations of hydraulic capacity. In this study, qualitative assessment took into consideration the effects of the application of the Palmiter techniques on the St. Joseph and Tiffin Rivers.

Logjams were common and large on these rivers when Mr. Palmiter conducted his first large-scale application of the techniques in 1975 and 1976. Figure 3 shows debris characteristic of these jams in the Blanchard River at Ottawa, Ohio. In some situations, the channel had cut deeply into the banks in order to find a flow path around the obstacles (see Figure 4). By removing the jams, the cross-sectional area of the stream was increased by an amount that varied with the size of the jam. It also reduced the hydraulic resistance in that region both by the removal of the sources of minor head losses due to

Figure 3. Debris in Blanchard River at Ottawa, Ohio

Figure 4. Bank Cutting

constriction, curvature and enlargement and by lessening the value of Manning's n in the immediate area of the jam. By reducing the length of the flow path slightly, the slope of the water surface in that reach was increased and returned to a value closer to that in the river before the jam occurred. Major slope changes, such as are often done in channelization, either through cutting off oxbows or by frequent attempts to straighten the channel, have not been done on the restored sections of the St. Joseph or Tiffin Rivers in recent years. Without heavy equipment, such channel modifications would be difficult to make. To date, use of heavy equipment has not been a common practice in application of the Palmiter techniques.

Having made these assessments, the following assumptions regarding effects of the techniques can be stated:

1. In most instances, the brush piles along the bank have the effect of slightly increasing the hydraulic resistance of the channel above the value it would have had in the absence of the brush piles. However, the hydraulic resistance of the brush piles at the sides of the channel should be less than if the same amount of brush were more randomly scattered across the river or located in the central part of the channel.
2. Removal of bars reduces the channel roughness and increases channel cross-section.
3. Removal of potential obstructions reduces the chance of Manning's n increasing due to trees toppling into the channel.
4. Of all Palmiter's techniques, his use of riparian vegetation is the most important factor in maintaining hydraulic capacity. When the riparian vegetation is doing its job--reducing the entry of light into

the channel and inhibiting weed and tree growth in the channel--it also tends to maintain the value of Manning's n achieved shortly after completion of the initial work.

Field observation indicates that riparian vegetation such as is shown in Figure 5 does inhibit aquatic weed and tree growth in the channel. In contrast, the absence of riparian vegetation in conventional channel modification (including one-sided clearing) allows lush in-channel growth of both herbaceous and woody plants. This growth typically occurs as early as the next year after construction or even in the same year if the construction is done in the winter or early spring.

The effect of aquatic vegetation on channel roughness has been investigated for some conditions. Chow (1959, p. 102) reports an increase from 0.033 to 0.055 in one year during the spring of the year due to "bushy willows and dry weeds on the side slopes." Later in the season, the value of n increased to 0.115 at medium summer stages and 0.099 at nearly bankfull stage with "a thick growth of cattails on the bottom of the channel." After high water washed out the cattails, the value of n dropped to 0.072. Chow also observes "that trees growing on the side slopes do not impede the flow so much as do small bushy growths, provided overhanging branches are cut off."

Chow (1959, p. 102) recommended that drainage ditches in central Illinois be designed with a minimum n of 0.040, if weeds and bushes are removed annually, 0.050 if the channel is to be cleared in alternate years only, and notes that values greater than 0.100 may be found if the channel is not cleared for a number of years. Lower values were considered to be unrealistic and would lead to underdesign of a channel. In our interviews, we found no evidence that values even as high as 0.040 are being used in design practice. If

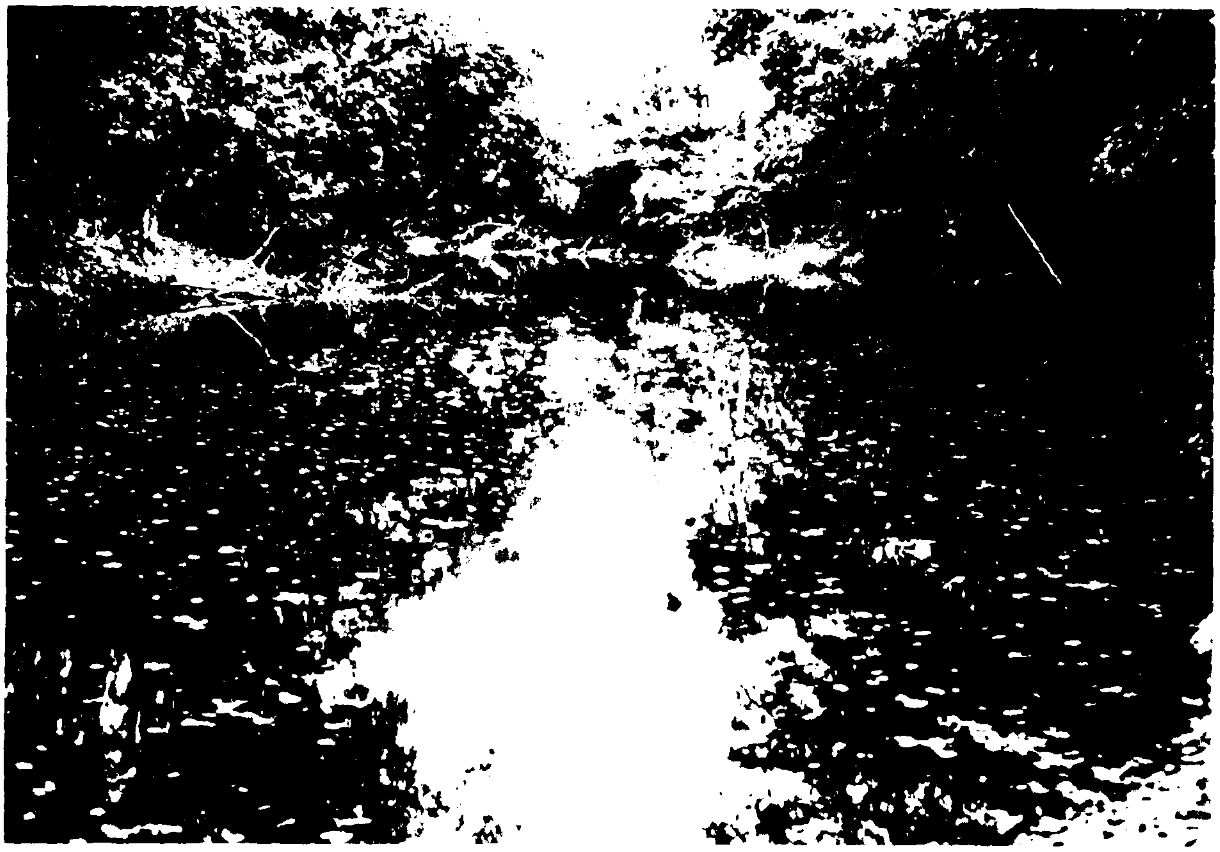

Figure 5. Mature Riparian Vegetation

Chow's conclusions are accurate and are applicable to streams of the kind being channelized in northwest Ohio and for which the restoration techniques have been considered applicable, the actual hydraulic capacity of channels may be as low as one-quarter of design capacity (0.025 divided by 0.1000).

Cowan (quoted in Chow, p. 106) developed a formula for calculation of n that adds several components of n together to get a total value. The value ascribed to "high and very high vegetation" (high and very high are not defined quantitatively in the Chow reference to Cowan) ranges from 0.025 to 0.100. With severe meandering, the effect of this component would be about 30% larger.

One of the important issues in using information such as that by Chow and Cowan is whether it is valid for streams like the St. Joseph, Tiffin, Blanchard, and other rivers. Without field measurements in reaches of the streams that might have vegetal growth of the kind described by Chow and Cowan, this is necessarily a matter of some conjecture. However, portions of these rivers are not much larger than some drainage ditches, with channel widths at top of bank being under 60 feet. In reaches of the St. Joseph and Tiffin Rivers that had no bank vegetation, the study team observed extensive herbaceous and woody plant growth in the channel. While these observations are not conclusive evidence of the applicability of Chow's conclusions to these streams, they are certainly not inconsistent with those conclusions.

To summarize this qualitative assessment, the effects of using the river restoration techniques on streams clogged with logjams or bars are an increase in cross-sectional area, slightly increased slope and decreased hydraulic resistance. If maintained as prescribed, the effects should be permanent. If compared with a channel modification project in which the riparian

vegetal canopy is removed, the principal advantages of the Palmiter techniques are the maintenance of the hydraulic resistance and cross-sectional area at fairly constant values, whereas the conventionally dredged channels may have a considerable increase in hydraulic resistance as measured by Manning's n.

Quantitative Assessment of Effects

On the Tiffin River in Fulton County, detailed cross-section surveys had been done for the Fulton County Commissioners by the Poggemeyer consulting firm. The surveys began at the Williams-Fulton County line and extended upstream to the U. S. 20 bridge, a distance of about 13.5 miles. These cross-sections were used to estimate some of the effects described above. Figure 6 summarizes the calculations.

The following assumptions were made:

1. A high frequency discharge of 600 cfs. At the lower end of the reach, this would be considerably below bankfull levels under normal flow conditions.
2. Manning's n of 0.040 and 0.080, paralleling the values suggested by Chow.
3. A damming effect at the lower end of the reach this was taken as 2 feet and 4 feet in successive calculations for both $n = 0.040$ and $n = 0.080$.

For $n = 0.040$ and no damming effect, the normal depth of the channel is calculated to be 4.47 feet at station 201. A calculation was made using an initial water surface elevation of 702 ft msl, which would correspond to a depth of 4.50 feet. The resulting water surface profile is the lowest of the five profiles on Figure 6. For the same flow, the normal depth for $n = 0.080$

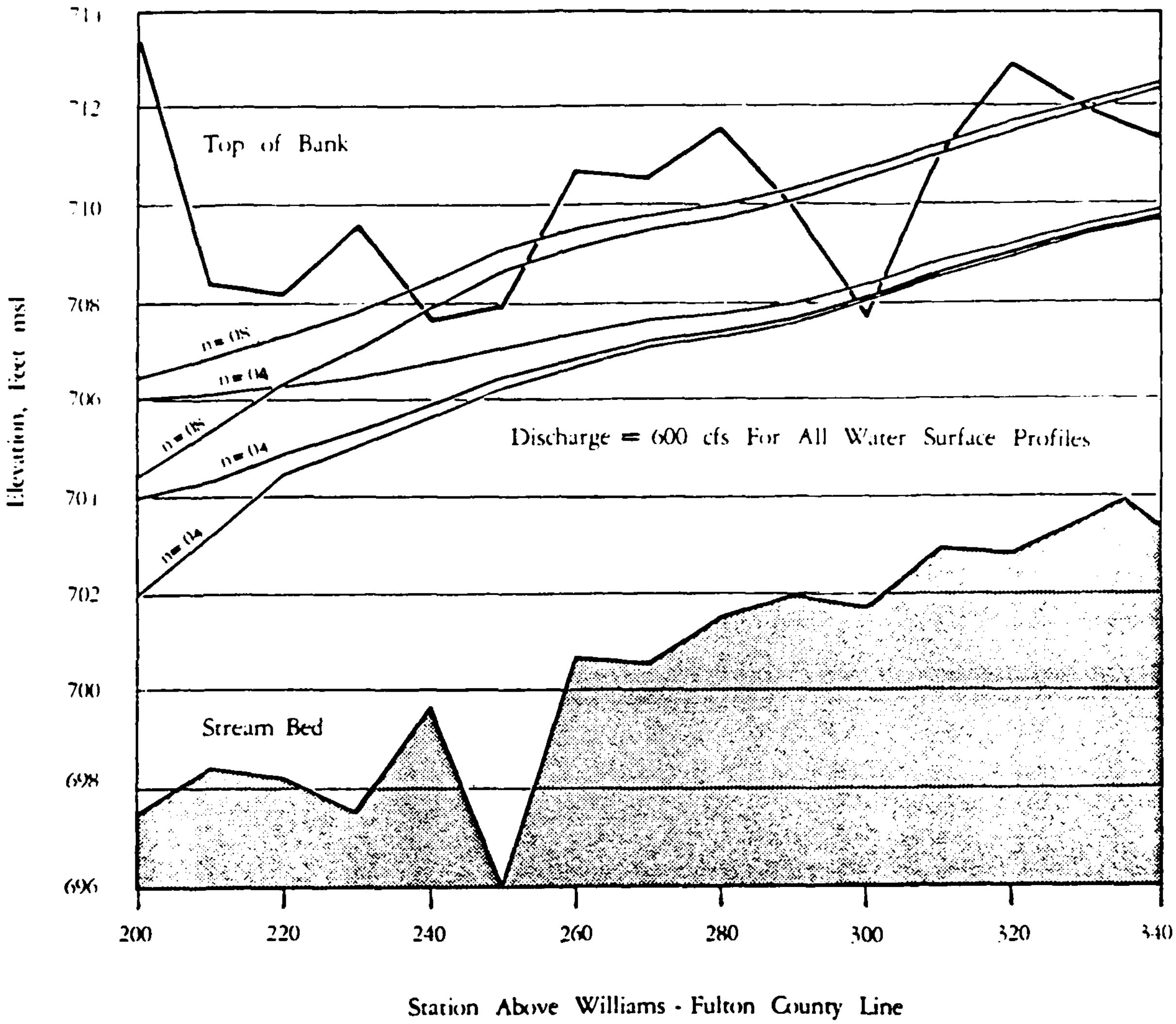

Figure 6. Water Surface Profiles, Tiffin River, Fulton County, Ohio

is 6.61 feet, 1.14 feet higher than for n = 0.040. The starting water surface elevation was taken as 704.5 ft msl, 0.39 feet higher than normal depth. The resulting water surface profile is the third from the bottom. This condition results in overbank flow at station 241, whereas overbank conditions would not be experienced with n = 0.040 for 6000 feet upstream.

The effect of slight damming, such as might be experienced with logjams or other obstructions, is estimated by assuming the water surface at the lower end of the reach was higher than the normal depth condition. Two and four feet are reasonable estimates of the amount of damming that might be encountered on this river. One such condition was measured in the field at a point farther downstream, below Stryker, at a flow of 220 cfs. The head loss across the jam was 2 feet. The jam itself, Figure 7, was not as severe as others that have been observed and/or removed on the Tiffin River.

With a 2-foot damming effect and a Manning's n of 0.040, overbank conditions are not experienced until station 300, 10,000 feet upstream. With a 4-foot damming effect and Manning's n of 0.040, the overbank condition is experienced at the same place, but is slightly higher.

With a 2-foot damming effect and a Manning's n of 0.080, overbank conditions are reached at station 240, 4000 feet upstream from the beginning of the reach. The profile for a 4-foot damming effect and a Manning's n of 0.080 is not shown, but conditions are reached at about station 209, a mere 900 feet upstream from the beginning of the reach.

The importance of these calculations is that they show how serious the effects of either an increase in Manning's n or the damming effect of a logjam can be on relatively small discharges. Flows that would be contained within the banks for conditions that will be referred to as natural (tree-lined banks,

Figure 7. Small Logjam, Tiffin River below Stryker, Ohio

no obstructions, and an n of about 0.040) will go overbank and flood adjacent fields or roads when either n increases significantly or there is downstream damming from obstructions.

As can be seen from the water surface profiles for $n = 0.040$, and as is characteristic of water surface profiles on mild slopes with downstream damming, the profiles converge at an upstream point. Thus, the critical aspect of flooding from the damming effect of obstructions such as logjams is how close the jam is to a vulnerable point in the channel, i.e., a point with a low bank. Damages will tend to be localized but may be severe and frequent.

CHAPTER 4

EFFECTS ON AQUATIC LIFE

Field investigations and secondary data studies of fish populations were conducted in the Tiffin, St. Joseph, and Blanchard River systems in northwestern Ohio and in Harker's Run in southwestern Ohio to determine the effect of the Palmiter restoration techniques on species diversity. See Figures 8-11. The diversity of fish species before and after restoration was chosen as an indicator of stream health, because it was felt that fish would respond rapidly to any habitat modification brought about by restoration work. Sampling methodology was limited to seining, and the data were collected too late in the year to be as useful as desired.

Initial Investigations

A trial sampling run to test equipment and procedures was conducted on the three northwestern Ohio river systems in November, 1979. All sampling sites except Bean Creek (the upper Tiffin River) had undergone restoration at least one year prior to the sampling of fish. Bean Creek is a channelized stream and is confined between man-made levees during a portion of its length.

The collection technique used was seining. Water depths of 5 feet and more in the lower Blanchard and Tiffin Rivers made sampling difficult and it was too late in the season for the data to be as useful as desired. However, the fish that were collected indicated the existence of good stream habitat. Table 2 summarizes the results of those studies.

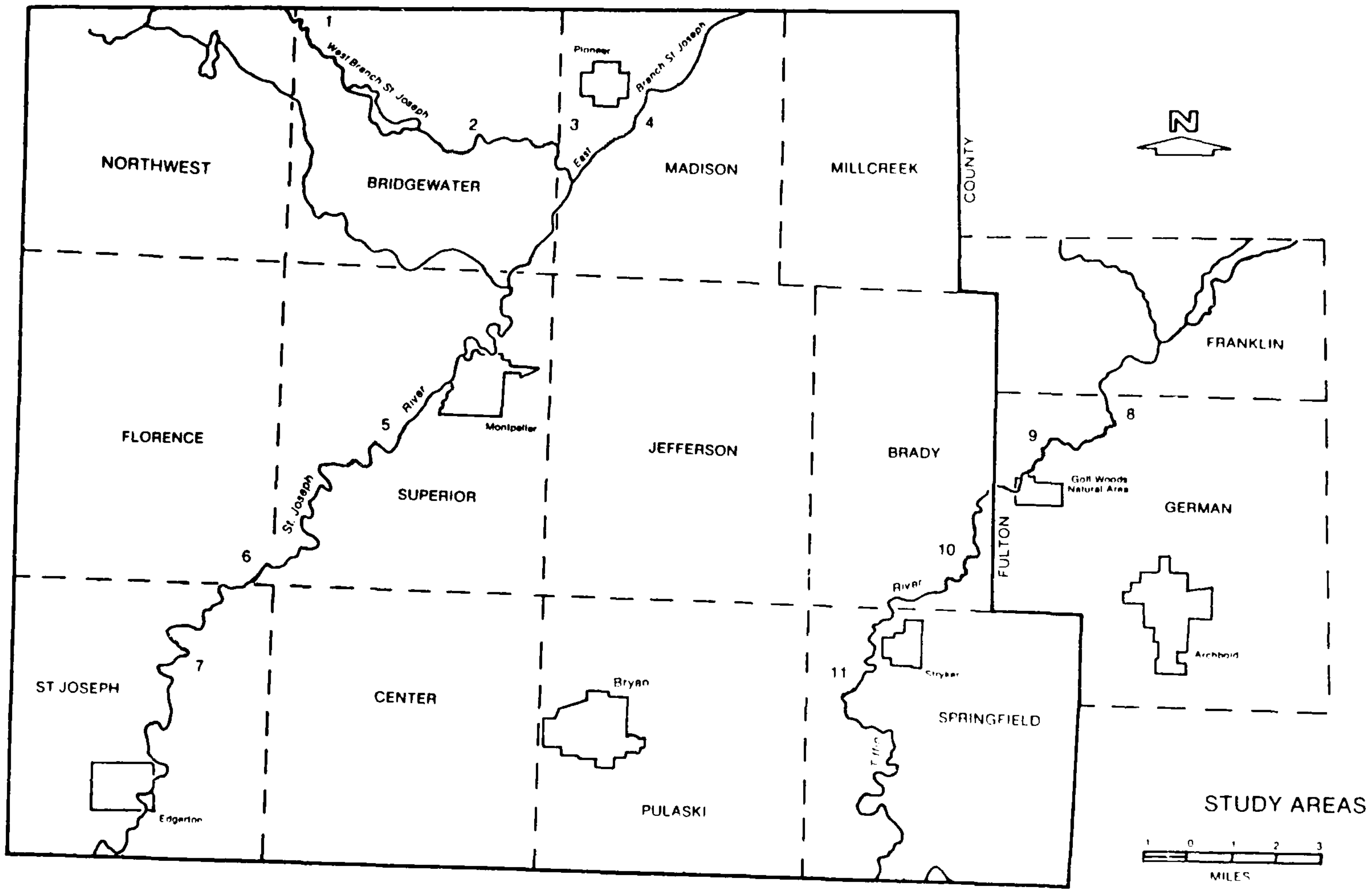

FIGURE 8. WILLIAMS COUNTY STUDY AND SAMPLING AREAS

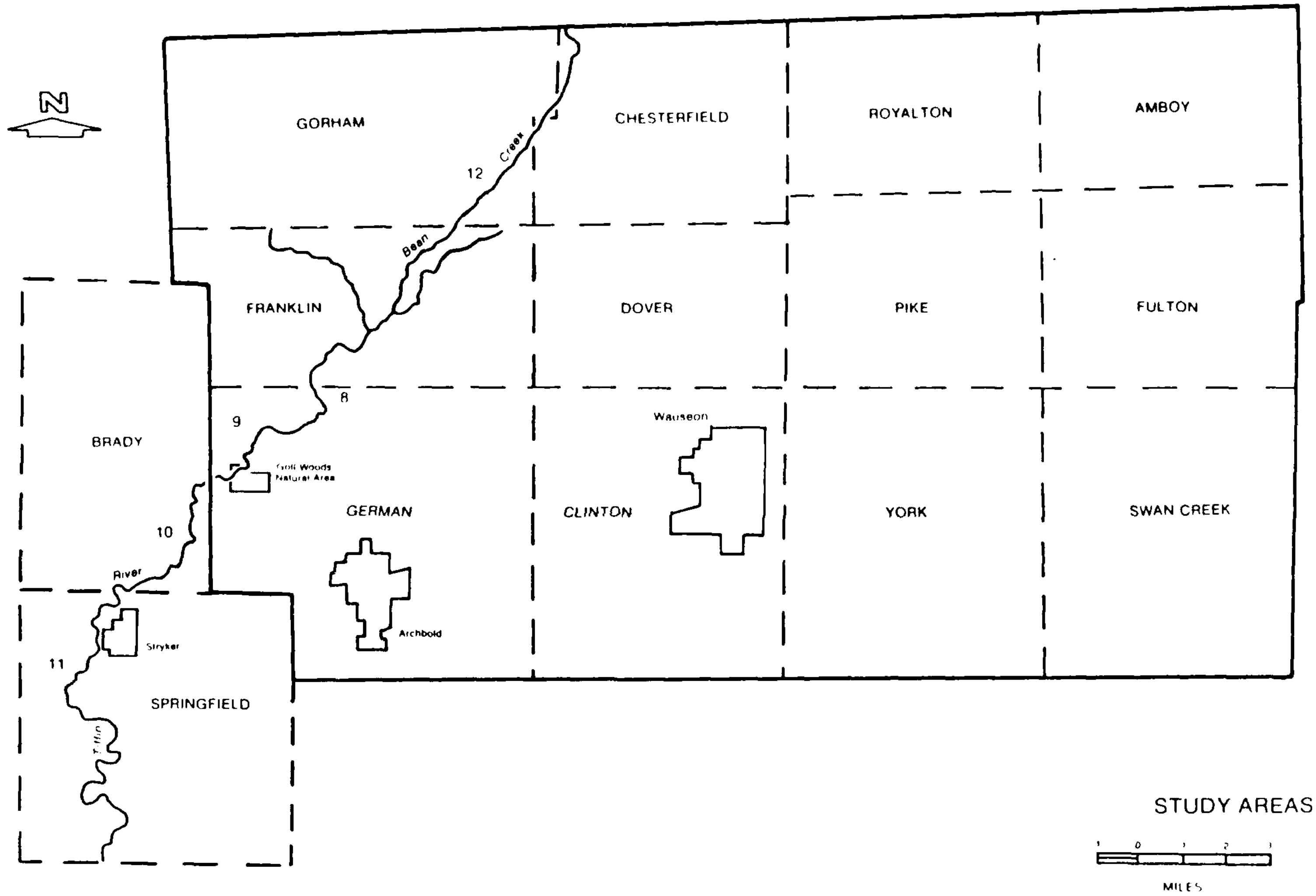

FIGURE 9. FULTON COUNTY STUDY AND SAMPLING AREAS

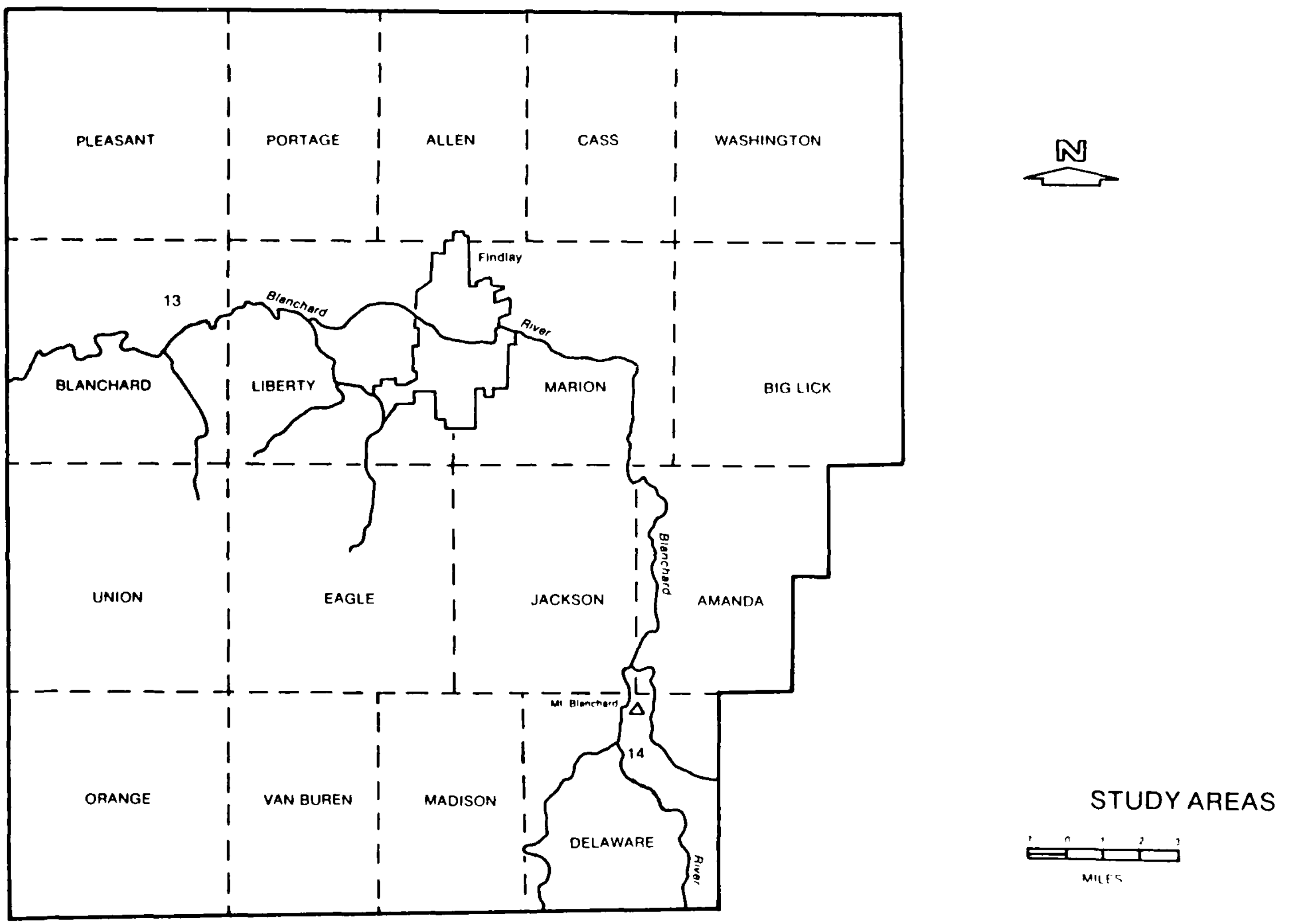

FIGURE 10. HANCOCK COUNTY STUDY AND SAMPLING AREAS

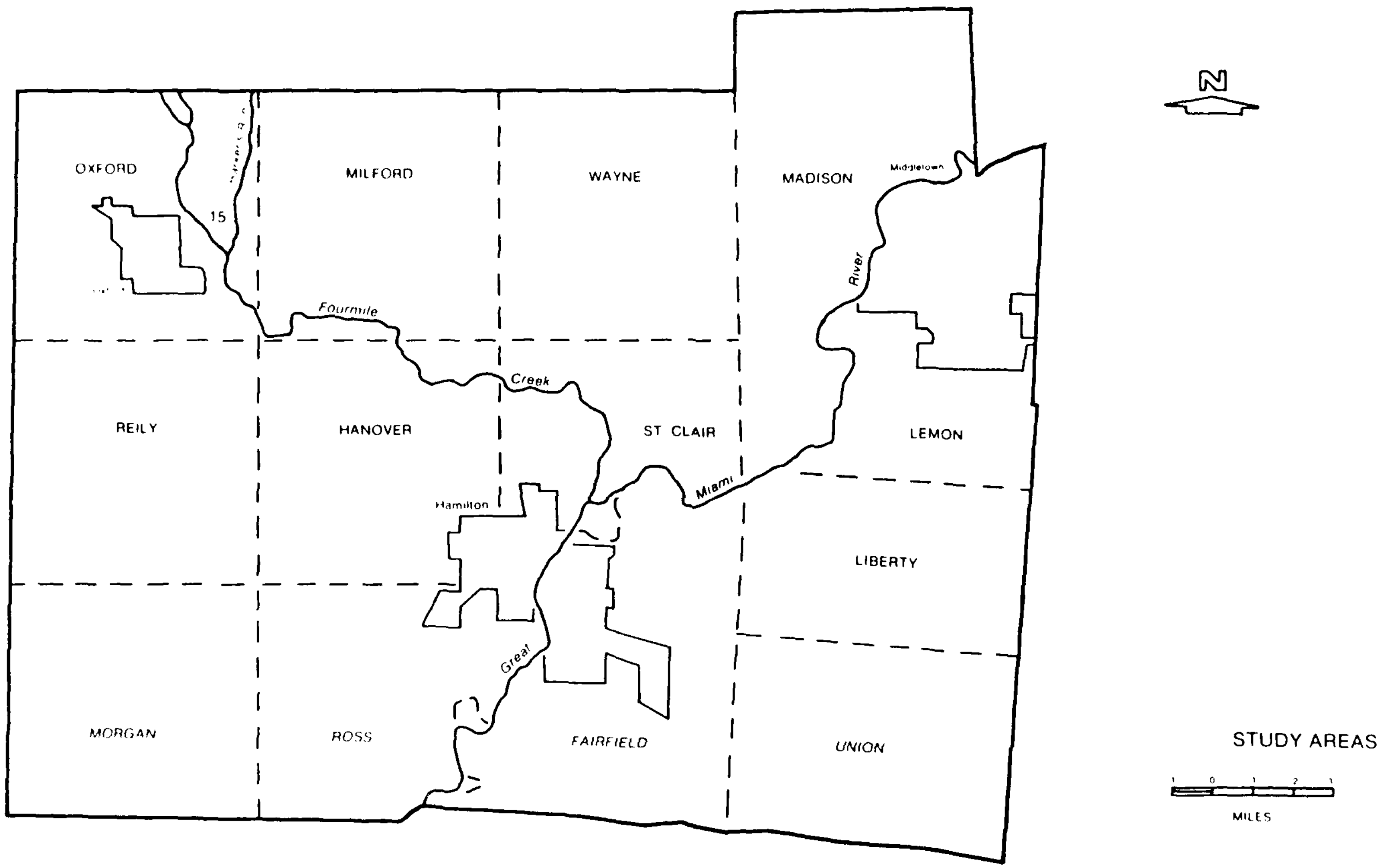

FIGURE 11. BUTLER COUNTY STUDY AND SAMPLING AREAS

Table 2. Fish Species Collected in Blanchard, Tiffin (Bean Creek), and St. Joseph Rivers, November 16-18, 1979

West Branch St. Joseph[1]	West Branch St. Joseph[2]
Creek chub*	
Hornyhead chub*	Hornyhead chub*
Central johnny darter*	Central johnny darter*
	Logperch darter*
Central redfin sculpin* (Northern mottled sculpin)	
	N. E. sand shiner*
Hog sucker*	

Blanchard[3]	Tiffin[4]	Bean Creek[5]
		Creek chub*
Greenside darter	Greenside darter	
Rainbow darter*		
	Bluntnose minnow*	Bluntnose minnow*
Suckermouth minnow		Suckermouth minnow
		Spotfin shiner
		Central stoneroller*

*Fish whose habitat is generally clean water.

[1]Location 1, Figure 8

[2]Location 2, Figure 8

[3]Location 9, Figure 9

[4]Location 12, Figure 9

[5]Location 14, Figure 10

Subsequent Sampling Efforts

In the early spring of 1980, it was learned that Mr. Palmiter had been successful in obtaining a CETA grant to work on the Tiffin and St. Joseph Rivers in Williams County. The prospect of this new work's being done seemed ideal in that it would allow fish diversity studies to be made on these rivers before and after treatment. To supplement seining, a pack-mounted electro-shocker was constructed.

Despite the existence of a rather detailed preliminary work plan, the CETA crews encountered many difficulties and delays due to a lack of expected state-purchased equipment and an unusually wet summer in 1980. Consequently, the sites selected for fish sampling were either not restored or were worked in an incomplete fashion. Despite these drawbacks, two major sampling trips were undertaken in June-July, 1980, and June-July, 1981. On the latter trip, the study team was assisted by personnel from the Columbus office of the U. S. Fish and Wildlife Service. For additional comparison and expansion of the time series, collections made by the Ohio Department of Natural Resources were also used.

For the seining operation, the following protocol was used. A reach of stream 50 meters long was selected so as to include both riffles and pools. Each end of this reach was marked with stakes and flags, and the reach was further subdivided and marked into 10-meter lengths. The bottom of the seine was placed at the lower end of the 50-meter reach and anchored on the stream bed with rocks. One person was stationed at each end to hold it. Two persons ("stompers") then went 10 meters upstream and waded downstream toward the seine, forcing any fish in the 10-meter section into the seine. When the two

"stompers" reached the seine, the seine was lifted from the water, the fish transferred to sorting pans and preserved with formalin in sample bottles.

The portable shocker was used especially along and under the banks and in brushpiles to obtain fish that could not be collected by seining. As soon as the stunned fish rose to the surface, they were collected with a dipnet and preserved with formalin in sample bottles.

After finishing the most downstream section of the reach, the seine was successively moved to the next upstream section and the above operations were repeated. Figure 12 is a seining operation in progress.

An additional complication to this study's planned fish investigations was weather. To supplement the electrofishing and seining, a creel census was planned for spring and summer, 1980. The objective of using a creel census was to get more of the larger game fish, a difficult task with the other fishing methods. A number of the best fisherman in the area were enlisted to assist in the census, a sampling plan was developed, recording sheets prepared, etc. High precipitation precluded execution of the census, even though several alternate dates were tried. The summer and fall of 1980 were characterized by high precipitation through much of those seasons. The late June sampling was virtually the last time during the summer when fish work was possible by means of seining and electrofishing.

To supplement the fish records collected in the field by this study, records were obtained from the Ohio Department of Natural Resources (ODNR) for the years 1979-1980. These records included some of the larger game species. ODNR routinely samples these streams on a rotational basis. Samples of the data were taken from sections of the St. Joseph and Tiffin Rivers in Williams County where stream restoration had taken place during 1975-1976, and of the

Figure 12. Seining

Tiffin River in Fulton County where channelization was being considered. This latter reach had a healthy stand of trees but had never been restored by Palmiter's crews. It had been channelized near the turn of the century. As may be noted in Tables 3, 4, 5 and 6, the similarity between the two is striking.

In Harker's Run, near Oxford, it was possible to do before and after sampling in connection with attempts that were made by the study team, with assistance from a Miami University work crew, to stabilize a stream bank and remove log jams in June, 1980. One sampling was done immediately before the modification, one shortly after the modification, and one more than two months after modification. Fish species collected are listed in Table 7.

In the Harker's Run data, populations after the restoration work were also diverse, including many species that are found in clean water habitat. The degree of alteration, while certainly significant, may have been too slight here to draw strongly affirmative conclusions about the effect of restoration on the stream.

Some characteristics of the fish species, with both common and scientific names, are given in Table 8. The characteristics noted are habitat-oriented.

These investigations are far from definitive. The single conclusion that seems merited is that, in the St. Joseph and Tiffin Rivers, where work had been done in 1975-1976 and later to a limited extent in 1981, the fish populations are diverse and include species that are predominantly characteristic of clean water habitat, thus indicating a healthy stream.

Table 3. Fish Species Collected in Tiffin River, Williams and Fulton Counties, October 1979, by Ohio Department of Natural Resources

Williams County

Brady Township[1]	Springfield Township[2]
White crappie	White crappie
Blacksided darter*	Blacksided darter*
Johnny darter*	Johnny darter*
Bluntnose minnow*	Bluntnose minnow*
Common shiner*	Redfin shiner
Common sucker*	
Orangespot sunfish	

Fulton County

German Township[3]	German Township[4]	German Township[5]
Creek chub*	Creek chub*	Common bluegill
White crappie	White crappie	White crappie
Brookside darter	Brookside darter	Bluntnose minnow*
Johnny darter*	Johnny darter*	Green sunfish
Bluntnose minnow*	Bluntnose minnow*	
Common sucker*	Common sucker*	

*Fish whose habitat is generally clean water.

[1]Location 10, Figures 8 and 9

[2]Location 11, Figures 8 and 9

[3]Location 9, Figures 8 and 9

[4]Location 9, Figures 8 and 9

[5]Location 8, Figures 8 and 9

Table 4. Species Collected in St. Joseph River by
Ohio Department of Natural Resources
September, 1980

Williams County

Florence Township[1]	St. Joseph Township[2]	Superior Township[3]
	Common bluegill	Common bluegill
	Carp	
		White crappie
Blacksided darter*		Blacksided darter*
Johnny darter*	Johnny darter*	Johnny darter*
Bluntnose minnow*	Bluntnose minnow*	
	Northern pike	
Gizzard shad		Gizzard shad
Emerald shiner	Emerald shiner	Emerald shiner
Spotfin shiner	Spotfin shiner	
Green sunfish	Green sunfish	Green sunfish

*Fish whose habitat is generally clean water.

Note: All sampling locations are below or in area where stream restoration work was done in 1975-1976.

[1] Location 6, Figure 8

[2] Location 7, Figure 8

[3] Location 5, Figure 8

Table 5. Fish Species Collected in West Branch of St. Joseph River near Boy Scout Camp, 1979-1981[1]

October, 1979 (by ODNR)	July, 1980 (by Miami Univ.)	June-July, 1981 (by Miami Univ.)
		Largemouth bass
		Rock bass*
	Common bluegill	Common bluegill
Creek chub*	Creek chub*	Creek chub*
		Hornyhead chub*
	River chub*	River chub*
Blacknose dace*	Blacknose dace*	
	Blackside darter*	Blackside darter*
Johnny darter*	Johnny darter*	Johnny darter*
Green sided darter		
Logperch darter*		
Rainbow darter*		
	Bluntnose minnow*	Bluntnose minnow*
		Mud minnow
		Golden redhorse*
		Common shiner*
	Rosy face shiner*	Rosey face shiner*
	Silver shiner*	
		Spotfin shiner
Common sucker*		
Hog sucker*	Hog sucker*	Hog sucker*
	Green sunfish	Green sunfish

*Fish whose habitat is generally clean water.

[1]Location 1, Figure 8

Table 6. Fish Species Collected in East Branch of St. Joseph River, 1980[1]

Miami University June	ODNR, September Madison Township Section 29E
	Common bluegill
Creek chub*	
River chub*	
	Johnny darter*
	Bluntnose minnow*
	Grass pike
	Gizzard shad
Rosyface shiner*	
Pumpkinseed sunfish	

*Fish whose habitat is generally clean water.

[1]Location 4, Figure 8

Table 7. Fish Species Collected in Harkers Run,* 1980

May 22*	June 12*	September 10*
		Creek chub**
		Blacknose dace**
E. banded darter	E. banded darter	
		Fantail darter**
Greenside darter		
Johnny darter**		
Bluntnose minnow**	Bluntnose minnow**	Bluntnose minnow**
		Fathead minnow
		Pugnose minnow
Silverjaw minnow**	Silverjaw minnow**	Silverjaw minnow**
		Sucker mouth minnow
		Gizzard shad
		Ohio rosefin shiner**
		River shiner
Silver shiner**	Silver shiner**	Silver shiner**
		Steelcolor shiner
Central stoneroller**		Central stoneroller**
		Common white sucher**
	Hog sucker**	
		Pumpkinseed sunfish

*Sampling location 15, Figure 11.

**Fish whose habitat is generally clean water

Notes:

May 22 was immediately before the stream modification.
June 12 was shortly after the modification.
September 10 was more than two months after the modification.

Table 8. Habitat Characteristics of Fish Species Collected in This Investigation

Fish Species	Habitat Characteristics
Largemouth bass (*Micropterus salmoides*)	Weedy or brushy, mud-bottomed, sluggish streams
Rock bass (*Ambloplites rupestris*)	Rocky streams
Common bluegill (*Lepomis machrochirus*)	Quieter pools in streams
Carp (*Cyprinus carpio*)	Warm rivers
Creek chub (*Semotilus atromaculatus*)	Creeks
Hornyhead chub (*Hybopsis bigguttata*)	Clear, gravelly streams, moderate size
River chub (*Hybopsis micropogon*)	Clear creeks and rivers
White crappie (*Pomoxis annularis*)	Turbid rivers; not averse to a mud bottom
Blacknose dace (*Rhinichthys atractulus*)	Small, cool streams
Blackside darter (*Hadropterus maculatus*)	Usually in weak currents of streams
Brookside darter (*Labidesthes sicculus?*)	Surface waters in lake-like habitats (?)
Eastern banded darter (*Etheostoma zonale*)	Riffles of moderate-sized streams, particularly in algae and other vegetation
Fantail darter (*Etheostoma flabellare*)	Gravel bottom of slower and shallower riffles in small streams
Greenside darter (*Etheostoma blennioides*)	Prefers riffles where rocks are coated with green algae
Central Johnny darter (*Etheostoma nigrum nigrum*)	Quiet water, sandy bottom
Logperch darter (*Percina caprodes*)	Sandy to bouldery riffles of medium-sized streams
Rainbow darter (*Etheostoma caeruleum*)	On gravel in creeks
Bluntnose minnow (*Pimephales notatus*)	Clear streams over firm bottoms
Fathead minnow (*Pimephales promelas promelas*)	Silty streams

Table 8 (cont.)

Fish Species	Habitat Characteristics
Mud minnow (*Umbra limi*)	Streams with soft bottoms, sluggish or even stagnant habitats
Pugnose minnow (*Opsopoeodus emiliae*)	Sluggish, generally weedy waters
Silverjaw minnow (*Ericymba buccata*)	Shallow, sandy streams
Suckermouth minnow (*Phenacobius mirabilis*)	Clear to silty streams
Northern pike or grass pike (*Esox lucius*)	Cool to moderately warm, generally weedy, sluggish rivers
Golden redhorse (*Moxostoma erythrurum*)	Clear creeks and rivers
Central redfin sculpin or Northern mottled sculpin (*Cottus bairdii bairdii*)	Cool creeks
Gizzard shad (*Dorosoma cepedianum*)	Clear to very silty water, large rivers
Common shiner (*Notropis cornutus*)	Cool creeks
Emerald shiner (*Notropis atherinoides*)	Large rivers
N. E. sand shiner (*Notropis deliciosus stramineus*)	Flowing pools and quiet stream riffles
Ohio rosefin shiner (*Notropis ardens*)	Clear, swift creeks
Redfin shiner (*Notropis umbratilis cyanocephalus*)	Sluggish, muddy streams
River shiner (*Notropis blennius*)	Deep, wide waters of silty rivers
Rosyface shiner (*Notropis rubellus*)	Clear, swift streams
Silver shiner (*Notropis photogenis*)	Flowing pools and riffles, clear, swift streams
Spotfin shiner (*Notropis analostanus*)	Medium-sized, often silty, rivers
Steelcolor shiner (*Notropis whipplei*)	?

Table 8 (cont.)

Fish Species	Habitat Characteristics
Central stoneroller (*Campostoma anomalum pullum*)	Clear, gravelly brooks and creeks
Ohio stoneroller (*Campostoma anomalum anomalum*)	Clear brooks, creeks and small rivers; essentially a ripple form
Hog sucker (*Hypentelium nigricans*)	Riffles of clear streams
Common (white) sucker (*Catostomus commersonnii*)	Small to large streams, most frequently in clear waters
Green sunfish (*Lepomis cyanellus*)	Sluggish creeks
Orangespot sunfish (*Lepomis humilis*)	Silty water
Pumpkinseed sunfish (*Lepomis gibbosus*)	Weedy parts of streams, cool to moderately warm waters

Note: Brookside darter is presumed to be a reference to brook silverside. However, it may also be a miscopied entry referring to a blacksided darter.

Scientific and common names of fish, as well as habitat descriptions, are taken from Fishes of the Great Lakes Region by Carl L. Hubbs and Karl F. Lagler, The University of Michigan Press, Ann Arbor, 1958, third printing, 1970.

CHAPTER 5

PERCEPTIONS OF TECHNIQUES BY LOCAL OFFICIALS

Success in employing the river restoration techniques in the areas of northwestern Ohio where Palmiter has worked is dependent on the cooperation of local officials. Of particular importance is the support of county engineers and commissioners and district conservationists of the Soil Conservation Service.

As part of this study, interviews were conducted in four northwest Ohio counties. The Palmiter techniques have been employed in this area, although channelization of ditches and streams has long been the accepted method of rapidly removing water from agricultural fields. The face-to-face interviews in Defiance, Fulton, Hancock and Williams Counties were conducted in August and September, 1980. County engineers, county commissioners, and conservation officers were selected for interviews because of their influence in making channel modification decisions. All were long-time residents in their counties, and most have owned or rented farmland for many years. An analysis of the responses to the questionnaire follows. Numerical summaries of responses are given in Table 10. The instrument is found in the appendix.

Defiance County

Five officials were interviewed. In regard to the flooding frequency of the Tiffin River, the average response was that the river threatens flooding in the county about once every 2.9 years. Only one respondent responded

to the question concerning the flooding frequency of the St. Joseph River. It was his opinion that it flooded once every two years.

When questioned about what problems flooding caused in the county, most responded that the major concerns were the delay of spring planting, closing of roads and bridges, destruction of crops in late spring and early summer, and the erosion of adjacent farmland. Two respondents replied that such flooding is expected in owning bottom land and was just part of the risk involved in farming on such property. It was widely argued that property owners who benefit from river restoration activities and state and federal agencies should pay for flood protection work. One respondent felt there should be a county-wide ditch tax.

With respect to the use of various flood control techniques, it was generally felt that channelization was effective, at least in the short term, if managed correctly. It was noted, however, that work done on the Little Auglaize River had tended to give channelization a bad name. Regarding the use of Palmiter's techniques, several were concerned about the problems that might be caused downstream, from debris and sediment released from restored reaches upstream. Several felt that grass growing on the river bank is a more effective method of controlling erosion than trees, and that farmers will not accept the planting of riparian trees. Most agreed, however, that it was too early to judge the long-term effectiveness of the techniques.

Fulton County

All four officials interviewed in Fulton County considered flooding a major problem on the Tiffin and felt that serious damage was done once every two years. Major concern was focused upon the delay of spring planting, the

destruction of crops in spring or early summer, the closing of roads and bridges and the erosion of adjacent farmland. All felt that protection of farm property was a cost to be borne by the landowners who ultimately benefit from the work.

All respondents stated that traditional channelization was an appropriate means to minimize flooding and that some protection is due to farmers. The main problems perceived to be associated with channelization by the respondents were increased erosion rates, destruction of scenic areas, improper channel design and the political-social unrest that such projects generate. Several felt that flooding in Fulton County was particularly severe because of the rapid decrease in river gradient as the Tiffin flows from the morainal terrain of Michigan out onto the flat lake bed of the former Pleistocene Age Lake Maumee. Rapid sedimentation resulted from the reduction of river velocity. Filling of the channel with sediment was a major concern of two respondents. They felt that the channel should be deepened to increase capacity and one person suggested that the State of Michigan should be asked to join Ohio in dredging the material.

The tenor of comments concerning the Palmiter techniques was generally unfavorable. It was felt that they were a good first step in increasing channel capacity, but that his methods would not be enough to solve the county's flooding problems. There was universal concern that the log-jam debris would cause problems to landowners downstream. Several felt the trees along the banks do cause flooding and thus should be cut back far enough to allow grass to grow. Palmiter's work was thus thought to be poorly suited and overrated for use in Fulton County.

Hancock County

With respect to their perception of flooding of the Blanchard River, most thought that it rose above its banks once in three years. In contrast to the responses in the other three counties, respondents were particularly sensitive to loss of personal property and damage to houses caused by flooding in Findlay, Ohio, during large storm events. Delaying of spring planting, destruction of crops in the spring or early summer, erosion of farmland, and the closing of roads and bridges were also considered major problems.

When questioned about the merits of channelization, most felt it had the potential of reducing flood damage and to control erosion if it were "done right." Several felt the Blanchard should be dredged and the channel improved to reduce flood losses and that the work should be paid for by watershed residents. Although channelization was recognized as causing a loss in esthetic and recreational value of the river, it was generally felt that the overall benefits outweighed these costs. As one respondent replied: "The county would still be black swamp if it were not for channelization."

Reaction to work done on the Blanchard (on which Palmiter was a consultant) was generally favorable, although again the question of the fate of log debris released from jams was raised. Concern was also raised about the slow progress of work performed by the unskilled CETA crews. It was felt that the effect his work would have on flooding would be localized. Overall, however, respondents felt the river work was good, that it maintained a healthy riverine environment and that it did reduce erosion and increase capacity of the Blanchard.

Williams County

The six officials interviewed in Williams County estimate the frequency of flooding at once ιour years on the Tiffin River and once in three years on the St. Joseph. As in Defiance, Fulton, and Hancock Counties, the major problems created by flooding were considered to be the delay of spring planting, the destruction of crops in spring and early summer, closing of bridges and roads and erosion of farmland.

There was a greater feeling than in the other three counties that channelization was not cost-effective. Many felt this technique of flood control caused erosion, eliminated fish pools, reduced vegetation and lowered the level of the water table in the channelized drainage basin. The use of channelization in drainage ditches was thought to be necessary by many.

Palmiter's techniques generally received favorable ratings, although one person stated that he felt his methods were overrated and another said he was in favor of more "drastic methods" such as pulling the logs in a jam completely out of the river. There was a more widely-held feeling in this county than in the other three that the best way to protect farmland on the floodplain is to leave riparian vegetation on the stream bank and to keep the rivers free of obstructions. This, of course, is Palmiter's contention as well, and this premise probably reflects the "missionary work" that Palmiter has done in his home county. It was also felt that the cost of such work should be borne by state or county funds.

Summary

Table 9 presents a summary by county of the perceptions of those interviewed. One interesting observation concluded from these interviews is

that, although 10 of the 17 officials feel the benefits of channelization out-weigh the costs, 15 out of 19 feel the benefits of Palmiter's techniques out-weigh their costs. It appears, therefore, that there is a greater consensus among these officials that the restoration techniques are more cost-effective than are traditional channelization methods.

Table 9. Perceptions of Local Officials Concerning Methods of Stream Modification

County	Effectiveness of Restoration Techniques	Effectiveness of Channelization
Defiance	Too early to tell	Effective, if [illegible] well, in short term
Fulton	Inadequate, overrated	Appropriate
Hancock	Localized, generally good	Has potential, loss of [illegible]-thetics
Williams	Generally good	Not cost effective, but necessary in drainage ditches

Table 10. Interview Summary

		Fulton	Defiance	Williams	Hancock
I. Threat of flooding					
Serious problem on:					
Tiffin River	Yes	4	4	3	N/A
	No	0	1	3	N/A
St. Joseph River	Yes	N/A	1	3	N/A
	No	N/A	0	3	N/A
Blanchard River	Yes	N/A	N/A	N/A	4
	No	N/A	N/A	N/A	1
Problems created by flooding:					
a. Spring planting delays					
Major problem		3	1	3	1
Problem		1	3	3	3
No problem		0	1	0	1
b. Crop destruction (spring/summer)					
Major problem		4	2	2	2
Problem		0	1	4	3
No problem		0	2	0	0
c. Closing roads and bridges					
Major problem		3	2	1	0
Problem		1	0	3	5
No problem		0	3	3	1
d. Damage to houses, buildings					
Major problem		0	0	0	1
Problem		2	0	0	3
No problem		2	5	6	1
e. Damage to personal property					
Problem		2	0	0	3
No problem		2	5	6	2
f. Erosion of farm land					
Major problem		2	2	1	1
Problem		2	3	3	4
No problem		0	0	2	0
Have you seen logjams on river?					
Yes		4	4	6	5
No		0	1	0	0
Would logjam removal make a big difference to flood problems?					
Yes		2	5	6	5
No		2	0	0	0

Table 10 (cont.)

	Fulton	Defiance	Williams	Hancock
Do trees on banks and floodplains contribute to flood problems?				
Yes	4	2	1	2
No	0	3	5	3
Do trees on banks and floodplains prevent erosion of fields?				
Yes	2	4	6	4
No	2	1	0	1
Should flood plains used for farming be protected from flooding?				
Yes	3	1	3	2
No	1	4	3	3
Should effort be made to maintain or increase number of trees?				
Yes	2	1	2	3
No	2	3	4	2
II. Flood Control Techniques				
Is channelization effective for:				
a. Reducing flood damage				
short term	3	5	3	4
long term	3	3	1	4
b. Increasing channel capacity				
short term	3	5	3	4
long term	4	4	3	4
c. Controlling erosion				
short term	2	1	0	3
long term	1	1	0	3
d. Changing stream alignment				
short term	3	5	5	4
long term	4	4	4	4
e. Providing outlet for tile drains				
short term	3	5	4	4
long term	4	5	4	4
f. Maintaining stream habitat				
short term	2	1	0	2
long term	1	1	1	3
g. Maintaining esthetic features				
short term	1	1	0	2
long term	0	1	1	2
Are there enough benefits of channelization to justify costs?				
Yes	3	3	1	3
No	0	1	5	1

Table 10 (cont.)

	Fulton	Defiance	Williams	Hancock
Are you familiar with Palmiter's techniques?				
Yes	4	5	5	5
No	0	0	0	0
Have you seen any places where he or his crews have worked				
Yes	4	2	4	4
No	0	3	2	1
III. Effectiveness of Palmiter's Techniques				
a. Reducing flood damage				
short term	3	1	5	4
long term	0	2	5	2
b. Increasing channel capacity				
short term	3	2	6	5
long term	1	2	5	3
c. Controlling erosion				
short term	4	3	6	4
long term	2	2	5	2
d. Changing stream alignment				
short term	2	3	3	2
long term	1	1	3	2
e. Providing outlet for tile drains				
short term	1	0	2	2
long term	0	0	2	2
f. Maintaining wildlife habitat				
short term	4	5	6	5
long term	3	3	6	5
g. Maintaining scenic features of streams				
short term	4	5	6	5
long term	3	3	6	5
h. Problems with his methods				
short term	4	4	3	3
long term	0	1	3	2
i. Benefits outweigh costs				
Yes	1	5	6	3
No	3	0	0	1
IV. Public Complaints about Flooding				
Delay of spring planting	4	0	0	0
Destruction of crops in spring or early fall	4	0	2	1

Table 10 (cont.)

	Fulton	Defiance	Williams	Hancock
Destruction of crops in fall	1	0	0	0
Closing of roads and bridges	4	0	0	0
Damage to houses and other buildings	1	0	0	0
Erosion of farmland	3	0	0	0
Reduction of recreation quality along river	0	0	0	1
Logjams	4	1	0	3

CHAPTER 6

EVALUATION

An overall evaluation of the restoration techniques used by Palmiter requires consideration of effects on hydraulic capacity and aquatic ecosystems, as well as of some of the claims and counterclaims about the techniques. As indicated in Chapter 3, the primary objectives of channel modification are to increase the hydraulic capacity of a channel and to reduce stream bank erosion. In northwest Ohio, the former objective is often discussed in terms of providing an effective outlet for tile drains. The criticisms of channelization (channel dredging with partial or full clearing of bank vegetation) usually center on disruption of aquatic ecosystems, failure to achieve increased channel capacity, inability to control bank erosion, and increase of flooding outside--usually downstream from--the channelization project boundaries. The following evaluation of the restoration techniques is based upon their effectiveness and facility of planning and execution as compared to the objectives and criticisms of traditional channelization techniques.

Hydraulic Capacity

As indicated in Chapter 3, where the channel is clogged with debris or bars, or resistance is high due to substantial growths of aquatic plants, the restoration techniques are capable of increasing hydraulic capacity. The upper limit on the channel capacity which can be achieved is the capacity of the

channel under quasi-natural conditions. The term "natural" seems unwarranted because man's activities have caused a deviation from natural conditions by conversion of swamp, marsh, and forest land into agricultural and urban land uses, with attendant increases in peak runoff and sediment loading.

In contrast to the upper limits of channel capacity attainable with the restoration techniques, channelization can achieve greater capacities by creating greater cross-sectional areas throughout a channel's length and increasing channel gradients over at least a part of its length. This is achieved at considerable initial cost and often requires substantial maintenance expense.

The restoration techniques increase channel capacity by increasing local cross-sectional area (removal of jams and bars) and by decreasing the hydraulic resistance of the channel. If hydraulic resistance is already low (say, Manning's n of less than about 0.035) or if there are no obstructions to flow, then one can not expect to achieve much, if anything, by use of the techniques. This, of course, is not usually the case, and the number of situations where there is clogging and hydraulic resistance is high is large enough to make the techniques of considerable interest.

Floating Debris and Sediment Removal

One of the controversial points about use of the methods is what happens to floating debris and sediment released in the channel by cutting up debris and removing bars. The view held by Mr. Palmiter is that, if cut into sufficiently small lengths, typically 4-8 feet, fallen trees, branches, etc., will be washed onto the flood plain not far below the point where they have been cut and be retained there.

From our observations, we believe this claim is usually, but not always, warranted. It also depends on such local conditions as whether there is a flood plain, whether there is access to the flood plain for such material to exit the channel, and whether there are any barriers, such as bridge piers, that will catch the debris before it reaches such an access point. There are situations where jams occur not far upstream from a bridge and where there is no significant flood plain between the jam and the bridge. There are other streams, deeply incised, where there is no significant flood plain for a considerable distance below a jam. In such instances, it is probable that debris will be caught and create a new problem.

It is clear, therefore, that there is evidence to support both sides of the debris controversy. It is also apparent that, when debris accumulation does occur, it can be dealt with through an ongoing maintenance program which is neither expensive nor elaborate.

The results of this study indicate that maintenance is important in stream restoration. Spotting new problems and correcting them, adjusting previous work, and fostering the growth of bank vegetation are the principal elements of maintenance.

Sediment which is removed by streamflow from mid-channel bars continues to move downstream. This sediment either concentrates as point bars in meanders downstream or may develop into midchannel bars to create further problems. Such accumulations could be removed in later maintenance work if they seriously decrease the channel's cross-sectional area.

Biological Effects

As stated in Chapter 1, the data base on biological effects collected in this study is too small to make conclusive evaluations. Nevertheless, on the basis of the evidence to date, there appear to be positive effects. Since not all the restoration projects executed to date were performed strictly according to best practice, the evaluation is a composite evaluation of what should occur under good conditions.

First, shading of the stream maintains low water temperatures which are comparable or identical to those in healthy, natural streams. This is regarded as being desirable for aquatic organisms. Second, the bank vegetation contributes food to the aquatic ecosystem. Detritus from falling leaves, twigs, etc., which falls in the stream has a positive effect on the macroinvertebrate community which in part feeds on detritus.

Third, the shading effect ordinarily results in the retardation or elimination of plant growth in the channel. This would generally be regarded as a positive effect. These effects on plant growth occur because of reduced light penetration into the channel. Palmiter's recognition of this relationship is probably his single most important contribution in developing the art of stream restoration. The effect on plant growth in the channel is augmented by the effect of the riparian vegetation root system on bank stability. The roots help hold the soil in place.

Fourth, the brushpiles and root systems are beneficial as habitat for fish. While perhaps not quite as good as a channel in which a great deal of the cross-section is choked with fallen trees and branches, it nevertheless provides good habitat. Again, the comparison with healthy, natural streams is

favorable. Habitat, in this case, is situated close to the bank rather than throughout the channel cross-section.

Overall Appraisal

As noted in Chapter 1, none of the individual restoration techniques is without precedent. The novel aspects of Palmiter's approach are: 1) the reasons for vegetal cover on the banks, and 2) the way individual components are assembled into a package.

Combining debris removal (the principal component of a clearing and snagging operation) with the construction of brushpiles as bank protectors (a direct application of river training works using soft jetties) enables the practitioner to use low-cost materials, unskilled and semi-skilled labor, and little heavy equipment. The river itself provides some, often much, of the energy required to correct the problem. It is, however, necessary to wait a period of time for the correction to occur, in constrast to the immediacy of the changes which occur through channel dredging. Channel adjustments in response to restoration efforts will occur continuously so long as there is flow in the stream channel. The adjustments are greatest when the flow is high. Thus, much of the correction is likely to occur before it is needed to cope with flows of flood magnitude. In what may be a near worst-case situation, large adjustments would occur during the flood event itself. In the case of dredging, on the other hand, if aquatic weed growth occurs in the channel before the channel capacity is needed to handle a large streamflow, some of the capacity will be lost because of increased hydraulic resistance and somewhat reduced cross-sectional area.

As to the effectiveness, there is little question that the restoration techniques are beneficial. For streams with significant obstructions by debris

or bars, or one or both bare banks, several [illegible] clude reduction of bank erosion, increase in [illegible] bar formation, and stabilization of both channel and [illegible] tic life is better than [illegible] channel had been dredged. [illegible] these benefits, it appears the entire package of [illegible] ployed. It isn't enough, for example, just to [illegible] guiding the current and vegetating the banks.

It is emphasized that the effect of channel [illegible] est for high-frequency (low to moderate flow) events. [illegible] because the changes are being made in the channel, where the obstructions to flow are located, rather than in the floodplain, which may carry a significant portion of the flow for the largest events.

Planning the Project

A major difference between use of the restoration techniques and channelization is the planning that precedes field work. In channelization, it is necessary to conduct cross-sectional and longitudinal profile surveys, which are then followed by hydraulic calculations. As practiced by Mr. Palmiter, the restoration techniques are planned qualitatively in the field. At its best, this is a combination of aerial observation and ground-level observation from the banks and from the stream channel. Field notes are written and photographs are taken which are then used by field crews to locate sites in which action should be taken to remove present and potential obstructions, build brushpiles, construct deflectors, remove bars, and establish bank vegetation. Good field notes are imperative to the successful implementation of a restoration project.

Project planning requires the development of an understanding of stream dynamics. This understanding is somewhat intuitive and comes through adequate training and experience. Instructions to field crews can be provided through a combi ation of diagrams and photographs. Three tape-slide shows, available from the Institute of Environmental Sciences, provide graphic instructions on how to plan and implement a river restoration project.

Experience acquired in this study indicates the desirability of conducting the aerial observations from a helicopter rather than a small airplane. The ability to hover in one place while making notes and determining accurate positions on maps and aerial photographs is a distinct advantage of the helicopter. However, it should be noted that Mr. Palmiter has been able to use the airplane effectively and others would too, if they have suitable experience and are familiar with the river system.

Compared to channelization, the cost of planning the field work is quite low. For example, even with the high cost of helicopters, the expenses of restoration planning will be considerably less than the amount required for the cross-section and longitudinal profile surveys and the hydraulic calculations that are normally done for channelization studies. The principal costs of planning, using Palmiter's techniques, are fees for consultants and other personnel, plane or helicopter costs, photographic costs, and boat rentals. The entire job can be done in a few weeks on reaches of stream up to about 60 miles in length, similar to those described in this report.

One of the real limitations in planning the work is finding a person competent in doing this type of field investigation. At the present time, few claim such expertise and, considering the totality of the techniques, few probably possess it. On the other hand, many have adequate expertise in judging

the characteristics of river flow in the field. Coupled with a general knowledge of the techniques as portrayed in this evaluation document and the accompanying instructional materials, it should be possible for many to acquire sufficient expertise to do a very creditable job of planning. With some experimentation and observation of the results over time, the development of competence should be a straightforward process.

Potential Problems Associated with Project Execution

Despite the seeming simplicity of Palmiter's restoration techniques, problems may arise if the methods are used incorrectly. There are several reasons why project execution might not be done well, including low levels of knowledge, inadequate supervision, and inappropriate implementation. For example, the project supervisor/planner may not be sufficiently familiar with the techniques and how they fit together. The work crews may not be well suppervised or there may be inadequate followup and evaluation following the initial corrective work. Another problem area is the failure to establish successional tree growth which will thrive and provide shade for the stream. Local experts in forestry and botany should, therefore, be involved in planning for the establishment of riparian vegetation.

Considering the totality of things that can go wrong, it is imperative that stream restoration not be thought of as something anyone can do with minimal training. Mr. Palmiter is very concerned that the restoration work be done correctly, so that the use of improper techniques does not tarnish its reputation. We share this view. Crews and supervisors should be well trained and adequately supplied with both work and safety equipment. Followup evaluations should be done regularly and corrective action taken when needed. Good field notes should be taken on work that has been accomplished.

Recommendations for Use

The usefulness of the restoration techniques obviously is greater in some streams than in others. A decision to use the techniques will be influenced by technical, economic, and policy factors. A summary of these factors is presented to provide some guidance in selecting candidate projects.

Technical and Economic Factors

Because the restoration techniques are effective in dealing with specific problems, one or more of those conditions should be present. These conditions include:

-- Stream obstruction by large debris, such as log jams;

-- Stream obstruction by bars in the channel;

-- Absence of vegetation on one or both banks;

-- Bank erosion.

The economic factors derive from the kinds of damage from flooding or erosion being experienced in the area. In general, there must be flood damage from high-frequency events in order for there to be a chance of economic justification. Similarly, bank erosion and channel conditions must either be causing direct dollar damage or interfering with recreational or wildlife uses (for which dollar estimates of damage are harder to obtain). Historically, the initial restoration efforts were attempts to improve navigation characteristics for small recreational boats.

An additional factor that has a bearing on the economic viability of a restoration project is institutional and management capability. As stated earlier, the techniques need to be carefully tailored to the situation--which requires skill and knowledge in the planning and design stages--and the field work must be carefully executed. After completion of the initial project,

ongoing monitoring and corrective maintenance should be done. These requirements seem to demand institutional stability and continued, albeit small, funding in perpetuity. The shortcomings of the work undertaken on the Tiffin and St. Joseph Rivers are entirely in the lack of a mechanism for ensuring monitoring and maintenance. Such agencies as the Corps of Engineers, Soil Conservation Service, Tennessee Valley Authority, and some conservancy districts would appear to have the capability of performing these functions.

Policy Considerations

When local interests request assistance from the Corps of Engineers in dealing with a river problem, they may have some objectives that are not articulated in the formal request. However, it is probably unusual for there to be a request in the absence of some real problem. Because so many local requests are not funded by the Federal Government for action by any agency, and because other projects may be funded years after the initial request is made, there is likely a genuine and important place for the restoration techniques in addressing river problems raised by local interests, even though use of the techniques might not meet all of the local objectives.

Agricultural land flood damages, for example, are often caused by high-frequency floods and bank erosion that cuts into fields, reducing the amount of tillable land. Stream restoration might be employed to reduce such damages. The rapidity and low cost of planning, design, and field work are very attractive features of the techniques.

It would be expected, in this example, that local interests would sometimes prefer not using the restoration techniques. Such a situation could arise if the most important local objective was protection from large, low-frequency floods. A restoration project could achieve enough economic benefits

by reducing damage from the more frequent floods to make a larger project uneconomical. However, when the choice may be between more rapid action and realization of benefits by use of the restoration techniques vs. delays of many years, if ever, in getting the larger project, it would be logical to assume that, in many situations, the restoration project would be preferred.

Another policy issue is that of funding responsibility. If federal agencies can engage in restoration projects, with concomitant sharing of costs, local interests are more likely to consider a restoration project than if all costs had to be borne by local interests. (It is worthy of some note that some of the restoration projects have been done with local funds, and that others have been done with federal funds not normally associated with federal water resource management, namely the CETA Program.)

Apart from considerations of the responsibility of the several levels of government and the sharing of costs among them, restoration would likely emerge as a preferred approach under the current federal water resource objectives. On both national economic development and environmental quality objectives, the techniques are attractive. The low cost, low maintenance features of restoration coupled with the achievement of flood damage reduction from high-frequency events are advantageous on economic grounds. Stream habitats are likely to be superior to most, if not all, alternatives on environmental grounds. Energy requirements are also low.

A final policy consideration is that a restoration project could be regarded as the first stage of a process of alleviating flood and erosion damage. In this case, a river would have time to adjust to a more stable condition before an agency undertakes subsequent stages. This could lead to better projects in the long run.

Recommendations for Future Research

While conducting this exploratory investigation, several research needs were encountered that could not be addressed adequately by the study team. These needs are briefly outlined here so that other research units or operating offices of the Corps of Engineers might carry on this work and fill in the gaps in knowledge.

One important gap in knowledge is how well a river restoration project holds up over an extended period of time. With the earliest major project's having been done in 1975, there is a brief period of operational experience. The briefness of the period is compounded by the lack of adequate records on what was done in the early projects. It would appear that the most appropriate strategy would be to follow several projects from pre-construction stage through construction and for an extended period of time after construction.

As an integral part of the long-term studies, and as part of short-term studies as well, good studies of hydraulic effects are needed. These studies should measure the hydraulic properties of streams before and after restoration. Determinations of Manning's n, or other measures of hydraulic resistance, channel cross-section, and channel and water surface gradient are needed. In at least some of the studies, sediment measurements should be made.

A gap in the hydraulic literature was on methods to estimate head loss across log jams. In many respects, it is an understandable gap because so much of the channel hydraulics literature is devoted to head loss over long reaches. However, if one focuses on local flooding and frequent floods, the importance of such obstructions is substantial.

Although we believe we have accurately and adequately portrayed the general nature of vegetation effects, this needs additional refinement and generalization. In particular, additional work is needed on the best ways to establish riparian vegetation and obtain rapid succession. There are important regional differences in species that are appropriate to riparian vegetation establishments. We have not been able to deal with this at all.

The streams we studied were limited to those in northwest Ohio. The techniques are now being applied in other parts of the country, notably in the southeastern states, and in soils that differ greatly from those found in northwest Ohio. The effectiveness of the techniques in these other settings should be studied. One expected finding is that stream adjustments would be much more rapid in streams with sandy beds and banks. By contrast, streams with rock beds and banks should experience slow changes other than for those changes brought about simply by removal of obstructions and potential obstructions. Vegetation effects would be expected to vary somewhat in arid regions where the stream may be dry for some portion of each year.

Cost analyses for both initial construction and maintenance are needed and can be obtained only by actual projects or, in the case of initial construction costs, by careful and detailed development of construction plans and cost estimates.

River restoration, with its flood damage reduction value's occurring primarily with high-frequency, smaller events, fits in naturally with flood plain management services and technical assistance programs. While some flood damage reduction will occur from the restoration work itself, it will work even more effectively if riparian residents are aware of what it is to do and how it does it. Technical assistance programs could show what can be accomplished

by restoration projects. Emergency warning and evacuation programs can be extended into these high-frequency events.

From the standpoint of those actually undertaking restoration projects, there are some equipment needs that are at present unmet. Saws that operate underwater without difficulty, safety equipment, and small field equipment to help maneuver cut logs would all be welcomed by field crews.

It seems certain that there could be refinements in project planning. Our study team recommended to Mr. Palmiter the more extensive use of black-and-white photographs to be used by field crews and it has been a useful technique. There are undoubtedly other techniques that could make project planning easier and better.

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